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ABSTRACT

A video performance monitoring system was developed by the URS/Matrix Company, under contract to the USAF Human Resources Laboratory and was evaluated experimentally in three technical training settings. Using input from 1 to 8 video cameras, the system provided a flexible combination of signal processing, direct monitor, recording and replay options including fast, slow, and stopped motion. The system design was based on hypothesized benefits or manpower savings in technical training, achieved by the remote and/or recorded monitoring of trainee performance, and the standardization of measurement criteria using recorded performance samples. The system was demonstrated in jet aircraft mechanic performance testing, in the screening of candidates for power lineman training, and in the evaluation of instructor trainees. The system was found to be feasible in many training environments and for most training tasks.
(Author/PF)

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HUMAN

RESOURCES

**DEVELOPMENT AND EVALUATION OF VIDEO SYSTEMS FOR
PERFORMANCE TESTING AND STUDENT MONITORING**

By

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July 1974

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This final report was submitted by URS/Matrix Company, 7245 Arlington Boulevard, Falls Church, Virginia 22042, under contract F41609-72-C-0021, project 1121, with Technical Training Division, Air Force Human Resources Laboratory (AFSC), Lowry Air Force Base, Colorado 80230. Mr. Arnold L. Hanson, Instructional Technology Branch, was the Laboratory contract monitor.

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MARTY R. ROCKWAY, Technical Director
Technical Training Division

Approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A video performance monitoring system was developed by the URS/Matrix Company, under contract to the USAF Human Resources Laboratory (AFHRL/TT), and was evaluated experimentally in three technical training settings. Using input from 1 to 8 video cameras, the system provided a flexible combination of signal processing, direct monitor, recording and replay options including fast, slow, and stopped motion. The system design was based on hypothesized benefits or manpower savings in technical training, achieved by the remote and/or recorded

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monitoring of trainee performance, and the standardization of measurement criteria using recorded performance samples.

URS/Matrix designed and procured assembly of a presumed cost-optimized system, using commercially available components. The system was demonstrated in jet aircraft mechanic performance testing, in the screening of candidates for power linemen (pole climbing) training, and in the evaluation of instructor trainees. Research findings and recommendations were reported. Instructions for further use of the system were developed, and the system was delivered to AFHRL for USAF application.

SUMMARY

Problem

Performance testing and student monitoring in individualized training are frequently labor intensive activities. The overall objective of this project was to investigate the feasibility of using low-cost video monitoring and recording equipment to extend the instructor's capabilities in both testing and monitoring activities.

Approach

Technical training activities at Sheppard Air Force Base, Texas, were evaluated and testing activities in jet aircraft training, power production, and instructor training were selected for study. A detailed analysis of the testing areas was conducted and a video system was designed to accommodate video monitoring and recording of student testing and training activities. The designed system was then tried out in the training environment.

Results

Most of the activities recorded or monitored provided adequate information to the instructor to accomplish his tasks. Frequently the video provided more information than was available without it. There were some technical problems associated with using or installing video equipment. The video techniques were usable in a wide range of training environments.

Conclusions

The use of video monitoring and recording equipment is feasible in many (but not all) training environments and for most training tasks. The use of video recordings can improve performance testing. There is a requirement for additional research in this area.

PREFACE

This report documents a comprehensive analysis of an experimental video system and guidance for use of that system. Research was accomplished under Project 1121, Advanced Technology for Air Force Technical Training. Dr. Marty R. Rockway was the Project Scientist and Mr. Arnold L. Hanson was the Task Scientist.

Research contained in this technical report was conducted under the provisions of Contract No. F41609-72-C-0021 with URS/Matrix, 7245 Arlington Blvd., Falls Church, Virginia 22042, for which John F. Hayes was the Senior Staff Scientist, and Edgar L. Shriver was the Consultant.

The authors wish to acknowledge Mr. William E. Hudson, Training Research Applications Branch, Sheppard Air Force Base, Texas, for making the scheduling possible, and the many other persons there who participated, particularly MSgt J. H. Phalan and SSgt Masters.

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SECTION 1.0 PLAN AND OBJECTIVES

Research performed under Contract F41609-72-0021, "Development and Evaluation of Video Systems for Performance Testing and Student Monitoring", was to explore the potential of video systems. URS/Matrix provided an experimental video system, initial experience in its use, and guidance documents to which USAF personnel can refer in using that system to extend and expand the capabilities of USAF instructors in student monitoring and performance testing.

To accomplish this investigation, a four-phase project was undertaken. Phase I was directed at selecting training and testing applications to serve as vehicles for the research, and designing a prototype video observation system. Phase II was devoted to acquiring the video system and to developing a rationale to guide its implementation. Phase III was an experimental application of the system to USAF training, and Phase IV developed guidance documents which describe how such systems can be designed and employed.

This report describes work performed between 15 March 1972, and 28 September 1973.

1.1 HYPOTHESES

Video systems have most typically been used as instructional tools to present information to the student. They provide a medium of storage for instructional materials, and the role of the instructor is to call those materials up for presentation at the appropriate time. This project, however, was designed to examine how such systems can be employed to expand instructor capabilities by displaying information about the student to the instructor; in effect, to "turn the camera around," so that the instructor can more effectively observe while the students perform.

The general hypothesis assumed by this project was that video observation can be employed to expand an instructor's capability, permitting him either to monitor the performance of more students, to monitor the same number more effectively, or to adopt more effective testing and training techniques such as performance testing and guided practical work.

Several underlying assumptions were contained in that hypothesis: One was that the most effective method of training, and of evaluating personnel being trained for technical jobs, is through the employment of practical work and criterion-referenced performance testing. Another was that a main deterrent to the use of such techniques is the amount of time, equipment, and individual attention required to employ them.

It was further recognized that the USAF technical training system provides an ideal laboratory in which to develop video techniques for performance testing and student monitoring, and it was assumed that Air Force training would benefit from such a development.

1.2 OBJECTIVES

The Air Force technical training system is a labor intensive enterprise. Because of the heavy emphasis on "hands-on" experience, there is need for instructor personnel to continuously observe and guide students during both training and testing. The demands placed upon the instructor in performing these functions are further aggravated (a) in situations where students are spatially dispersed and (b) in individualized training systems where students are progressing at their own pace and where testing may occur on an unscheduled basis.

The overall objective of this effort was to develop, evaluate, and assess the costs and benefits associated with a video system, one which could extend the instructor's capability to conduct performance testing and student monitoring in an Air Force technical training environment. Accomplishment of that overall objective involved the following subordinate objectives:

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To evaluate commercially available video components and to prepare a specification for a low cost video system (of commercial components) capable of accomplishing the specified tasks.

To procure and operate the designed system in a technical training environment.

To test a quantified, video recorded, performance test scoring system for use in technical training.

To develop sample sets of video recordings, and procedures for their use in training and standardizing the grading/rating practices of performance test scorers.

To develop a two-way communications system to permit student-instructor interaction.

To develop a user-oriented handbook to be used in selecting and using video systems in testing and student monitoring.

1.3 ASSUMED REQUIREMENTS

Certain assumptions were made concerning the nature of the USAF training system and the video opportunities it might generate:

Since the Air Force technical training system is largely performance oriented, performance testing is an essential tool for accurately evaluating student achievement in that system. The basic measurement policy is to assess the attainment of training objectives which require student performance, by using performance test items to the extent practical. One of the key constraints associated with performance testing, however, is the limited availability of qualified instructors to monitor and score the tests.

With the advent of individualized instruction and individual pacing, the requirement for testing on an unscheduled basis will create an even greater problem. Techniques, hardware sets, and testing and monitoring systems are required which can enable the Air Force to minimize this difficulty, and to fully exploit the advantages of individualizing instruction without an unacceptable increase in the number of instructors.

An additional problem in performance testing is lack of objectivity in scoring the tests, especially when the test involves a process as

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opposed to a product. This is due, in part, to the frequent absence of performance standards for the process, and also to the fact that the tester is required to exercise judgements based on brief and often single observations.

Video tape recordings can be used, in effect, to change the process to a product. Recordings of acceptable and unacceptable performance can be repeated to create reproducible standards. The use of recordings can permit time compression, time expansion, or a freezing of time which will allow a more systematic look at those aspects which are relevant to acceptable performance. It can also make available a complete record of a student's behavior, for evaluation at a later time, if on-line scoring is not feasible.

Students in an individualized mode proceed at different rates, frequently work in different locations, and tend to become dispersed over both time and distance. Despite that dispersion, the requirement to monitor and evaluate students and their progress still exists, and aggravates an already labor short situation. Unless some system for extending the capabilities of the available instructors is devised, a requirement for additional instructors is created.

Video technology appears to be a promising approach for extending the instructor's ability to monitor and direct students. It permits observations from remote locations, the monitoring of individuals or groups, the use of a variety of perspectives (some not possible with the unaided eye), and the collecting of recordings to be viewed at a more convenient time and/or place. Finally, student review of recordings can provide a unique kind of feedback. In general, the use of video monitoring appears promising as a means to increase both instructor and instructional efficiency.

1.4 PROJECT PLAN

To explore the potential of a video system in performance testing and student monitoring, URS/Matrix proposed a four phase plan:

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Phase I was a design study, and consisted of a study of the testing actually being conducted in USAF technical training. Tests were to be studied and evaluated, the testing environment analyzed, and a best-fit system of video hardware specified.

Phase II was to include the acquisition of an actual hardware system using off-the-shelf commercial components, and the development of metric techniques to be applied in Phase III.

Phase III was to consist of a field test in selected technical training environments. The video monitoring and recording system was to be evaluated, alternative strategies of employment developed, sample job-performance tapes recorded, and an assessment made of costs, personnel requirements, and the feasibility of applying the system. Recommendations were to be made for future research and development.

Phase IV was to consist of the development of user handbooks. Those handbooks have been prepared and delivered to the Air Force, separately from this report.

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SECTION 2.0 STUDY OF USAF PRACTICE

In order to recommend an optimal configuration for the proposed video system, it was necessary to acquire data concerning the real testing and training environment in which that system would be used. Therefore URS/Matrix personnel visited Air Force technical schools, and studied current testing practices in a series of representative technical training courses. Support to this effort was provided by the Technical Training School at Sheppard Air Force Base, Texas. Personnel in each Department of the School, upon being briefed as to what was desired, nominated specific candidate courses in their department for review and study by URS/Matrix project staff.

Four courses, with four specific performance measurement points were selected for continued study, of which three were ultimately used in the field tests (Sections 7.0, 8.0, and 9.0 of this report).

2.1 METHODS EMPLOYED

An analysis of the observation and testing requirements associated with the selected courses was subsequently undertaken, using the following techniques:

- Review of the performance testing materials utilized.

- Observation and filming of performance testing activity.

- Analysis of environmental factors.

- Laboratory investigation.

The first technique consisted of reviewing performance testing materials currently utilized in the four selected areas, to establish the observational requirements inherent in current procedures, and the types of performance being tested. Test scoring schemes were examined, as well as the relationship of performance test items to course objectives. The purposes of this review were to determine which student activities were

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useful to observe via video techniques, the amount of student observation that would be required, the feasibility of objectively scoring such activities, and the relevance of any performance test to the training objectives stated by the plans of instruction. These last two purposes supported a psychometric evaluation of the testing techniques being employed. Course materials were reviewed first; on completion of this review the testing situations were observed first-hand.

Study of testing method included interviewing instructor and supervisory personnel concerning the mechanics of each testing procedure, and the filming of sample situations for later analysis. Of particular importance were considerations such as student flow (frequency of testing, number of students, testing areas, etc.), instructor duties and assignments, and physical and environmental conditions. Interviews with staff members provided detailed information on administration procedures, potential and actual problem areas, the presumed value of a CCTV system to the testing situation, and system constraints imposed by school requirements.

Films taken of sample test performance were used to provide initial estimates of technical problems to be encountered. Preliminary estimates were obtained of required camera distances and angles, lighting, occlusion problems, and the clarity of areas to be viewed. Film provided a convenient and inexpensive medium for permitting more people to observe each testing situation without actually traveling to the site. Other matters that were observed included light levels, power sources, potential camera mounts, personnel traffic patterns, instructor/student communication requirements, sizes of the visual fields, and temperature/humidity conditions.

A studio/laboratory of the URS/Matrix facility was employed to study camera and recording problems in greater detail. Among operations explored in this environment were visual access via mirrors, the effectiveness of various kinds of mirrors, effects of the resolutions

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of various cameras on visual monitoring, effects of lighting variations, and capabilities of various lenses.

2.2 ANALYSES OF PERFORMANCE TESTING AREAS

Four courses were studied. They were the Jet Aircraft Mechanic Basic Course, the Civil Engineer Power Linemen Course, the Communication Equipment Repairman (teletype) Course, and the Technical Instructor Course.

2.2.1 Jet Aircraft Mechanic Testing The department concerned here was the only one which conducted performance testing as a function separate from training; a special section ran the testing program, and had a hangar area, aircraft, and personnel assigned to it for that sole purpose. The Jet Aircraft Mechanic Course was a high production course, receiving several hundred students each month. The course contained five "blocks" of instruction, and students were sent to the performance testing area at the end of each block. There they were put through a series of performance tests relating to the block of instruction which they had just completed. This testing was scheduled for six hours for each class, with class sizes ranging from eight to sixteen men.

The area selected for our investigation was the Block V test area. This consisted physically of an aircraft and three adjacent testing stations, plus a classroom just off the hangar area. A diagram of this area is included in Section 7.0 (Figure 12). The testing program included both written and job performance tests.

Typical Block V performance tests involved removing and replacing a flight control system component located on the underside of a wing, removing and replacing a wheel, checkout of the hydraulic system, checkout of the lighting system, inspection of the flight control system, checking inflation of tires, utilization of technical manuals to find information, and checkout and inspection of a battery. Many of the performance tests required that the student record his findings in

written form for evaluation, to reduce the workload on the test administrators. There were a total of 15 possible performance test items, of which each student was given eight.

Two test administration procedures were used. In the first procedure, students were given all the written test first, and then were scheduled through the performance tests on a sequentially assigned basis, allowing twenty minutes for each test item. During performance testing, there were from 8 to 16 students performing tests simultaneously, on different parts of the aircraft and at adjacent test mockups. Half of the performance items required that a test administrator check the student's work, indicating whether it was satisfactory or unsatisfactory. For the balance of the test items, the students recorded the results of their inspection or checkout findings on an acetate-covered form, using a grease pencil. Two separate sets of instructions and answer forms were used, so that the test administrators could grade one set, erase it, and assemble it for the third test cycle, while the students were taking the second test with the other set. This procedure required two test administrators to grade and record results during a twenty minute testing period, and a third to grade students taking those tests which required an on-the-spot check.

A second test administration procedure was used as much as possible, since it imposed less time and pressure on test administrators, but it could be used only when the class was small. Using this method, the students programed themselves through both the written and performance tests on an as-ready basis. All grading of tests was done at the end of the testing session. Two test administrators were then required, and they checked each student's work when he indicated that he was ready.

Testing techniques were set up to eliminate any requirement to continuously observe any individual test performance. Grading was done either by observing end-products, or by evaluating recorded answers. Performance tests were limited to tasks or sub-tasks that could be performed within a twenty minute time span. The technical documentation

available for use was extremely detailed. Virtually all tests were part-tasks; that is, they required the student to perform a limited subtask of a larger maintenance job. During performance testing, a student frequently asked questions to obtain clarification or information regarding the task; these were answered or not, based upon the test administrator's judgement.

From URS/Matrix analyses, several tests were identified for which full-time observation might be preferable to end-product observation.

2.2.2 Power Lineman Training Area A prime selection criterion for power linemen is that they possess the physical coordination (and other characteristics) necessary to learn to climb and operate from the top of 30-45 foot poles. To avoid investing training on individuals who were either incapable or unwilling to operate under such conditions, a pre-test was given to all entering students. It consisted of having them climb a 45 foot pole that was equipped with climbing steps, and another pole using leg spikes. The student's confidence and coordination was judged by an instructor, who observed them from the ground as they performed those two tasks.

This test offered an interesting analogy to the selection of paratroopers during World War II. At that time the first test of a paratrooper was to have him jump from a 34 foot mock tower. If he refused, or showed excessive fear, he was immediately washed out of training. In a special study of 1,300 men, thirty seven men refused to jump, but were allowed to continue the training anyway. Eighty-four percent (or 31 men) of this group of thirty-seven failed in subsequent training, in contrast to only 19 percent who failed in the remainder of the group.¹

At Sheppard AFB the pole-climbing pretests were conducted by instructors on a rotating assignment basis. The NCOTC of the training section

¹ The American Soldier, Volume II (pg. 216). Princeton University Press, 1949.

concerned had expressed interest in finding some mechanism which would permit him to personally evaluate a larger number of students, and further to critique his instructors on their evaluations. The critical factors to be observed during these evaluations were facial expression, arm-leg coordination, speed of ascent, and the ability to manipulate spikes. It was expected, of course, that untrained students would be awkward, especially in setting and removing the leg spikes. This was not of concern as long as "trainability" was evident.

Potential advantages of having such performances video-taped were identified as including the possibility that they could be reviewed by more than one instructor, that they could serve as a means of showing criterion performance examples to new instructors, and that they could serve as a means for critiquing student performance later in training.

The pre-testing area was located immediately behind the Civil Engineering Department's classroom and office facilities, and is diagrammed in Section 8.0 (Figure 17). Students were received in groups of 8-16 every three weeks, and testing occurred on Monday mornings. After the pre-test, each student was interviewed to confirm that he was willing to participate in the training and had no reservations about becoming a power lineman. Based upon the results of that interview and of the pre-test, an immediate individual decision was made as to whether to permit each student to begin formal training. Either the pre-test or the interview could be the basis for eliminating students at this point.

Normally there were two instructors assigned to conduct the pre-test. The test area consisted of one 45-foot pole equipped with climbing steps, and two shorter (30 foot) poles for testing spike climbing capability. Testing required approximately 5 minutes per student; approximately 90 minutes was required to test a full group of 16. The Departmental officers were approximately 500 feet from the test area.

Video cameras could be mounted at any desired distance from the target area. A major consideration, of course, was the ability of

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cameras to withstand a reasonable range of weather variation (wind, dust, rain, cold, heat, etc.). Due to the relatively long interval between testing periods, and the low student flow rate, it would be desirable that the cameras be convenient to mount and dismount as needed.

Instructor evaluations of the student's potential capability and willingness to climb were entirely subjective, and were based upon observations and experience which, of course, varied from instructor to instructor. Any time such evaluations are required, it is desirable to develop common standards to the extent possible.

Another phase of performance testing that was conducted in connection with the power lineman course took place at the end of each block of training. This testing was conducted in a different training area, consisting of a series of poles that were located approximately one-half mile from the classroom facility. Students had to perform such tasks as removing and replacing cross-arms, repairing insulators, and splicing cables. Typically, the instructor would sit on top of the pole and observe the student's performance. If there was power on the lines, the instructor would observe from a bucket truck, close enough to prevent accidents.

In evaluating performance on tasks conducted in this area, the instructor had a checklist that covered all aspects of the student's performance, from work preparation (putting on protective clothing) through mounting the pole, making the specified repair, following prescribed safety practices, to paper work related to the job. This meant that the instructor had to observe total task performance, treating each element as it was encountered. A majority of these tasks were two-man tasks; only one man, however, was evaluated at a time. The second man was essentially a helper, who followed the directions of the individual being tested.

These performance tests were based on much more objective grading criteria than those used for the climbing pretest. It was usually

possible to make a clear-cut determination as to whether a man had satisfactorily performed each task of the test. The only area of subjectivity was the judgement required by the instructor when the man was performing a task that required a helper.

There were a number of characteristics of this testing operation that affected video observation. For example, the exact site of testing changed periodically, due to poles wearing out, conflicts with other class operations, and class sizes. This meant that any permanently mounted video cameras would occasionally have to be removed. There was no building, or other suitable enclosure for equipment, closer than the classroom facility; thus a trailer or other small portable structure would presumably have to be provided. When students were performing with power on the lines, the instructor had to be able to stop them immediately if they were getting into trouble. In those areas where power was on the lines, it was essential that the instructor be in the immediate proximity of the students anyway, and remote video monitoring was not necessary.

2.2.3 Teletype Repairman Testing Upon completion of a three-week block of instruction in teletype repair, students in the Communications and Relay Center Equipment Repairman Training Course were given a series of performance tests. In these tests, the instructors placed one of a series of malfunctions into a teletype, and then had the students locate, identify and repair the defect. Testing occurred in the same room in which training had been conducted. A standard classroom contained six pairs of teletype printers, back-to-back, located in the center of the room. Between each pair of printers was a work table with a tool rack. The room was well-lighted and had ample power sources.

Typical repair problems which were inserted into the equipment consisted of a combination of mechanical and electrical malfunctions, and were a subset of those that students had encountered during training. The average time required for students to locate and correct these prob-

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lems ranged from five to fifteen minutes. After the instructor put the problems into the equipment, the students came into the room and turned on the machines to determine what the symptoms were. Working from the machine, his technical data, and what he had learned, each student diagnosed a suspected fault. When he thought he had correctly identified the problem, he wrote it down on a slip of paper and showed it to the test administrator, who told him either to go ahead and make the indicated repair, or that the defect he had indicated was incorrect. In the latter case the student returned to the machine and continued trying to identify the fault. The instructor gave only general information about his performance to the student if he was incorrect. He might tell him that he was close, or in the right general area, or that he was way off track. The amount and type of information given to the student seemed to vary a great deal during the time that these tests were being observed. Once the instructor had told the student to repair the machine, no further check was made on his work. Apparently it was assumed that once the student has correctly identified the problem, he could properly complete the repairs. During the time that this testing was observed no one failed a test. The overall testing environment seemed to resemble that of a controlled practice session, with assistance and guidance given as required.

The area within the teletype machine in which students worked was very confining. There was no need for continuous student observation, based on the way testing was structured, nor were there any critical safety demands. Traffic within the room was heavy, due to students leaving their work areas to show the instructor their written problem diagnoses. Between tests, all students left the room while new problems were placed into the machines.

Two instructors were used during testing. One moved about the room answering questions, while the other remained in one place and informed the students whether or not each had found the problem.

2.2.4 Instructor Training One of the technical training departments at Sheppard AFB had the additional duty of operating the Instructor Training Department. New instructor personnel assigned to the Technical School were sent to this department for training. In the course of this preparation, television was already being employed to tape student instructors' presentation in front of their classmates. These tapes were then used for student critique. In the latter phases of the program, instructors were assigned to the technical department of their specialty, to "practice teach" in those departments. Student instructors presented five such classes. During these presentations, the instructors were evaluated by personnel from both the technical department concerned and the Instructor Training Department.

Discussions with personnel in the Instructor Training Department indicated that at the time of URS/Matrix study, this department could seldom free personnel long enough to adequately observe and critique the sessions. They relied on the technical departments in which the students did their practice teaching to evaluate that performance. Instructor Training Department personnel observed the students' performance only when they were "instructing" their fellow classmates; this was an artificial situation, in which everyone was cooperative.

A video recording capability could be usefully employed during applied practice teaching to provide a semi-permanent record of student teaching performance, which could then be critiqued at a more convenient time and place by the Instructor Training Department. Additional benefits that a CCTV system might offer included allowing review by more than one evaluator, providing feedback and critique to the instructor, and providing a means of standardizing evaluation criteria.

The practice teaching sessions generally occurred in one of several specific classrooms, and consisted of conventional lecture presentations rather than labs or practical work sessions. The environment was a standard classroom, with the instructor giving a "standup" presentation.

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While the URS/Matrix team made no observations of these practice teaching sessions at Sheppard, an opportunity did arise to observe the video taping of a live classroom session in a different technical environment. This setting was a Coast Guard class in electronics maintenance. In this instance, a two-camera system was employed. A diagram of the classroom setup for this purpose is shown (as it was later used at Sheppard AFB) in Section 9.0 (Figure 18).

2.2.5 Comparison of Testing Environments Table 1 compares the four performance testing areas studied, across several dimensions, as they impact video system design.

The main problem to be encountered in the teletype environment would be that of installation. Space is limited, so suspended cameras would be required. These cannot be easily installed on a temporary basis. It was determined that this application would yield information comparable to that already available in the jet aircraft environment. It was decided, therefore, not to include teletype training in subsequent investigations.

The jet aircraft mechanic testing area contained both process-oriented and product-oriented tests. In addition, it presented several access and traffic flow problems, and could benefit from a semi-remote observation system. The instructor could be located in a central location with video monitors, and follow the action of several subjects simultaneously, hopefully giving all more attention than previously, with less movement about the testing area. This could provide the opportunity to examine span of control problems, as well as those involving the attainability of sufficient resolution and detail to permit evaluation.

The power lineman pre-test course provided an opportunity to examine several technical problems not present in other courses. The video system would have to be able to "track" a student over a relatively wide distance, with a remote-control camera which would be mounted out of doors. The testing evaluation criteria were quite subjective, and the

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TABLE 1. COMPARISON OF APPLICATION AREA CHARACTERISTICS

CHARACTER- ISTIC	TEST AREA			
	TELETYPE	JET MECHANIC	INSTRUCTOR TRAINING	POWER LINEMAN PRETEST
Available Light	High - Indoor	Average to low - Indoor	Average - Classroom	Very High - Outdoor
Power Access	Adequate	Poor	Adequate	None
Student Flow	High	Very High	High	Low (Once every three weeks)
Test Area Traffic	High - Confined Area	High - Confined Area	None	Low
Task Fineness	Very Fine	Very Fine to Gross	Gross	Gross
Safety Matters	Low	Low to Moderate	None	Moderate to High
Available Camera Mounts	Few	None	Adequate	None
Type of Testing	Product Oriented - Repair	Product and Process Oriented Repair	Process Oriented	Process Oriented
Potential for Video Increment	Low	High	Moderate	Moderate

focus of the study would be to determine whether standardization of evaluations could be facilitated by use of performance sample tapes.

Instructor training practice teaching was selected on the basis of its content, rather than technical considerations. The technical problem was to capture an appropriate mix of views of instructor and students, rather than extreme detail. The important evaluation would be whether a self-operated video system could provide a useful record of instructor performance in a live situation, and permit off-line evaluation of instructor performance.

2.3 CONCLUSIONS AND IMPLICATIONS FOR VIDEO SYSTEM SPECIFICATION

Review of USAF performance testing (described above) led to identification of typical testing patterns and environments, and preliminary identification of three testing tasks for use in test application of a video system. Further analysis of these tasks was undertaken to identify the characteristics required of a preferred video system. Not surprisingly, the final system configuration recommended was one which consolidated the several components, subsystems, and technical characteristics required by different tasks. Provision for interconnecting subsystems in a flexible manner would make it possible for such a system to meet a wide variety of potential future requirements for video monitoring and recording in human performance measurement.

The next subsection (3.0) contains the specification of a video system which satisfactorily meets all of these requirements and situations.

2.3.1 Nature of Performance Tests Performance tests can be classified as either process-oriented or product-oriented. Those which are process-oriented require observation and evaluation on either a continuous or intermittent basis; they demand more instructor attention and thus impose a heavier load on the instructor than product-oriented tests. This implies that any video system designed to cover process-oriented tests must provide both the mechanisms and the opportunity for the

instructor to observe the specified processes. It may require a system able to follow the performance activity over an area beyond the range of a single fixed camera, necessitating the use of multiple or remotely operated cameras. Process-oriented tests tend also to limit the number of simultaneous observations that can be made by a single instructor.

Product-oriented tests are those that result in the production of a defined end product, which can be evaluated by inspection upon completion of the task. Such products may take the form of an identified malfunctioning part (i.e., teletype repair), a completed connection or adjustment (i.e., aircraft maintenance repair), or even the answer to a written question. Product based tests reduce instructor evaluation and administrative loads, and are the most widely used form of performance tests. If there are a number of dispersed stations at which such tests are being taken, and if the instructor is required to continually move among them (as he does in the jet aircraft maintenance test), then video observation may offer a means of improving testing efficiency.

The relative degree of task grossness impacts the selection of a video system by establishing the size of the field which must be viewed. Fine tasks, such as those observed in the teletype repair tests, may require a viewing field of only a few square inches. As the distance of the activity from the camera increases, lens requirements change. More gross tasks, such as pole climbing, present much larger target areas, and tend to relax camera distance/lens requirements. The most stringent requirements are imposed when a performance test contains both gross and fine tasks. To monitor such tasks requires either multiple cameras or expensive lenses.

Also related to task discrimination requirements is the number of students normally undergoing performance testing simultaneously. When performance testing is normally a group activity, as opposed to a single student activity such as pole climbing, and when more than one subject is being graded at a time, the size of video field as well as target resolution are affected.

The student response mode was observed to vary considerably from one performance testing situation to another. Students were required to inspect, checkout, manipulate, answer orally or answer in writing, based upon the construction of the performance test. The nature of each response will establish the need for and/or feasibility of video performance observation. If the student must perform a visual task, it is imperative that the instructor either see the same view as the student, or else know exactly what that view is. He must further be able to verify that the student is performing the operation correctly. In the case of checkout, or other manipulative tasks of a sequential nature, the CCTV system must provide sufficient range and resolution that all operations can be followed, implying that wide-angle lenses or remotely-positionable cameras may be required. If verbal communication is required as a part of testing, an audio communication system may be necessary. "Communication" itself, however, can be achieved in different ways and further analysis was required to determine whether a single go/no-go system (e.g., lights, buzzers, etc.) would suffice in certain testing situations, or whether one or two-way voice communication would be required.

Written student responses ordinarily are not suited to video monitoring. When used in conjunction with performance testing, they represent one alternative means of solving some of the same observation problems which video systems address. When examining a performance testing situation for potential video applications, video cannot be recommended where a written response is feasible and sufficient. An example was seen in the jet mechanic testing area, where the current requirement was for the student to make a written response upon completion of a performance task such as an inspection or checkout. The ongoing testing operation continued to use his standard written response, but the video system was used to examine the content of his performance, to see what types of evaluation would be meaningful and feasible under video observation conditions, what advantages they might offer, and whether the written response was in fact sufficient.

The instructor evaluation mode is directly determined by the student response mode. The instructor may visually observe the student process or product, check it by touch (e.g., operation, checking for tightness), listen to a student explain his performance (e.g., teletype repair), or evaluate a written response. Visual requirements determine such CCTV system parameters as color, resolution, lighting, and special effects (e.g., slow motion, stop action), from which video equipment requirements are derived. If the instructor must physically touch the performance product, a video system will be of no use; in such cases, if video provides other advantages, then consideration may be given to altering both the performance and evaluation modes.

2.3.2 Environmental Characteristics of the Testing Area The physical location of the performance testing area and of the video monitoring area affects video system design in several ways. Location establishes the limits of accessibility to the target area, which controls camera angle and method of viewing. In combination with the size of the performance test object or work area, it dictates lens requirements. Location of the target area vis-a-vis obstacles and traffic constrains video camera location. Availability of power is a constant consideration; there are seldom enough readily available power sources. In the extreme case, this can lead to the need for a battery-powered system, or the installation of a new power supply. The relative dispersion of video target areas within the performance locale directly determines the number of cameras, and/or whether cameras must be fixed or adjustable.

The prevailing external environment in the testing area must also be considered in system design. Ambient conditions of noise, illumination, temperature, and humidity must be evaluated for their impact. Noise levels affect the kind of audio pick-ups used, since their sensitivity must be such as to pick up target sounds without undue masking noises. Illumination is critical to the sensitivity of the vidicon

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selected, as well as to camera position. Vidicons have specified illumination requirements, and must be matched to the environment; also, vidicon tubes develop "burn spots" if exposed to strong incandescent light.

Temperature and humidity levels must be checked for extremes. Most indoor locations present no problems, but outside locations can require the weatherproofing of exposed components. Dirt is another consideration, especially with recording equipment. Recording heads and tapes require relatively clean environments.

There are human factors aspects of the testing situation that affect system design. The traffic pattern in the area is a major consideration, since the objective is to be as unobtrusive as possible, and to impose no undue constraints on personnel in the system.

A particular consideration is that of safety. Many performance testing situations are in hazardous environments (e.g., high voltage, moving parts, dangerous liquids), and are set up for close instructor supervision. Remote video observation can remove the instructor or supervisor from the immediate locale, which may not be tolerable. If safety considerations are important, then the video monitoring system must provide the necessary safeguards.

2.3.3 Instructor Loading Factors A major objective of video monitoring is to expand or augment the instructor's capability; another is to provide him with access to events that were not previously accessible. In designing a CCTV system to achieve one or both of these objectives, one must insure that so many system tasks are not imposed upon the instructor as to reduce his effectiveness. Every additional demand made upon him (e.g., camera positioning, recorder operation, tape loading, etc.), must yield a gain sufficient to provide a net advantage.

2.3.4 Criterion Tape Production To make maximum use of a video observation system for performance evaluation and training, instructors

need to have available standards of correct performance against which to judge student performance. The proposed video system must therefore have the necessary equipment to produce such materials.

Criterion performance tapes will record and display controlled-production performances, in which a subject demonstrates the correct way of performing a task, and will possibly point out common errors for which the instructor should be on the alert. The use of such standards can reduce the variability of scoring practice among instructors, and insure that evaluations focus on critical rather than trivial or irrelevant aspects of performance.

2.3.5 Implementation Hypothesis Based upon analysis of the selected application areas, a more specific evaluation hypothesis was developed concerning how video observation techniques can be employed.

It was hypothesized that a video monitoring system can be provided that permits an instructor to remotely observe, critique, and correct the performance of physically dispersed students on practical exercises or performance tests, either in real-time or by recording such events for later analysis.

Such a system can further permit remote observation and critique of the performance of students operating in outside areas, and the recording of such events.

The system can make it possible for an instructor to record his own performance, in presenting instruction to actual classes, for subsequent review and critique.

The system can make possible the acquisition of video tapes of various levels of test performance, to be used to investigate methods of quantifying such performances. The resultant quantified performances could be used to examine ways of evaluating and improving reliability among raters of job performance tests.

These objectives can be accomplished without significant interference with the instructor's primary duties, or increases in operational personnel.

2.3.6 Hardware Requirements The minimum system capabilities which would be required to monitor and record student performance in each application area were identified, and expressed in terms of video hardware components. They were, listed by area:

In the Jet Aircraft Mechanic Test:

Four video cameras, with sufficient lens flexibility that shots could be achieved at distances from five to twenty feet.

At least one monitor for each of the four cameras, in order to study span of control.

One camera equipped for remote lens and remote pan/tilt operation.

A set of high quality mirrors, so that visual access to cramped working quarters can be secured.

An auxiliary lighting system for individual spot-illumination. No overall illumination system will be required.

A minimum of two video recorders that provide both time compression and expansion.

Two-way voice communication between the instructor and the student so that questions can be asked and instructions given.

Three cameras equipped with manual zoom lenses, to evaluate different camera configurations.

A split image capability, to evaluate the information yield of multiple images on a single screen.

In the Power Lineman Pre-test:

Two video cameras, one remotely operable and capable of tracking a student climbing to the top of a 45 foot pole within 30 seconds, from a distance of 50 feet. The second camera can be positioned manually.

A zoom lens capable of remote zoom from a field size of 7 feet in height to one of 2.0 feet in height, at a distance of 50 feet, to view arm/leg coordination and facial expression.

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Camera installation weatherproofed against rain, dust, heat and cold (20-110⁰F.).

A minimum of two video recorders, to provide both time compression and expansion of recorded sequences.

A camera vidicon capable of operating in bright sunlight (not directly into the sun).

In the Instructor Training Test:

A minimum of two cameras to provide a full view of the instructor and of the students throughout the presentation.

Synchronized playback of the two views, either through split-screen or other simultaneous viewing device.

A full and coherent audio pickup for the students and the instructor.

A camera to provide full coverage of a 20 x 30 foot classroom without operators.

Recording and other gear located in an adjacent area to reduce distraction.

Vidicon to operate in normal classroom lighting without augmentation.

Two video recorders, one of which will provide a time compression capability.

SECTION 3.0 SPECIFICATION OF HARDWARE

Based on the study of USAF testing practice just described (Section 2.0), a system hardware configuration was developed, capable of meeting specific video requirements of the three testing situations selected for detailed study, but with an additional potential for flexible application to job performance measurement elsewhere in the USAF training environment. In specifying hardware, URS/Matrix first made specific videotechnical decisions, in terms of numbers of channels, capabilities and limits of the system at each signal processing point, and of system constraints imposed by human engineering (operator) limits. When these decisions had been made and confirmed in terms of cost/benefit relations, they in effect specified a basic system within the state of the art (1972-1973). It remained to identify specific commercially available components, to combine them compatibly in an engineered system, and to build the system.

3.1 RATIONALE FOR SYSTEM SPECIFICATION

Specifications laid down by the Air Force in the original procurement request were the point of departure in designing system hardware. Those specifications were that the system would be:

Commercially available

Low cost

Mobile

Cover a wide range of detail and field

Easy to operate

Provide for both recorded and "live" observation

Provide slow, fast, regular, and stop speed capability on playback

Provide for audio 2-way communication

Be expandable to provide coverage of 12-15 students

3.1.1 Cameras A four camera system was at first recommended, based on a trade-off among factors of cost, coverage, and representativeness. It was considered that four video channels were the most which an instructor - console operator could monitor and control. Later it was recognized that additional cameras add little to cost, and substantially expand the range of the system. In particular, they are needed for situations in which several work sites exist, but may not all be active at any moment. The final recommended configuration included 8 cameras of which only 4 were continuously monitored.

An early decision, made on the basis of economic and technical considerations, was to rule out a color capability. As USAF practice was studied, this decision was checked several times to insure that color was not an absolute requirement in any situation being studied. This was confirmed sufficiently to uphold the original decision.

Color video systems exceed the cost of black and white systems by at least a factor of two. In addition, the current state of the art is such that color equipment requires more careful alignment, lighting, and environmental control than black and white equipment. The application environments under consideration in this project represented fairly severe conditions, and the video system could not be permitted to impose limiting demands upon the testing environment.

The selection of cameras was driven by lens requirements, costs, lighting, and the presence of certain other features of the system such as a special effects generator. Monochrome cameras for CCTV are virtually all equipped with vidicon tubes. These, as opposed to plumbicon or orthocon tubes, are inexpensive, reliable, and less complex to set up. They also produce less sensitive performance, but, unless color or "broadcast" quality is needed, are quite adequate.

Vidicon tubes are available in 1 inch or 2/3 inch sizes. The 2/3 inch tube is less expensive and gives slightly lower quality performance. The 2/3 inch tube, however, is not as flexible with respect to lens use,

since there is a narrower range of lenses available for use with that tube. For this project, analysis showed that lens flexibility would be critical, since the system must serve a range of applications in which ranges, angles and levels of detail would vary greatly. In a fixed, single purpose system, where lens flexibility is not critical, the 2/3 inch tube might be the more desirable. For our purposes, however, the 1 inch tube was required.

Camera sensitivity was established at a 0.1 foot-candle minimum. This required high sensitivity cameras. In establishing sensitivity requirements, a trade-off was made of costs for sensitive cameras, against the possibility of providing supplemental lighting. Where possible, this latter course is often less expensive. But in application areas where lighting was of concern to this project, such as aircraft hangars, supplemental lighting had to be kept to a minimum to hold down clutter.

Camera sensitivity is tied to another camera feature, that of synchronization. When multiple cameras are used, their signals must be synchronized--particularly when several monitors are to be observed (to prevent eye strain), when inputs are to be recorded, and when several cameras are to be fed through a special effects generator. In this project, all of these conditions were applicable. Some cameras provide random sync, which means there is no provision for imparting a common synchronization impulse. Others accept a predefined sync impulse (e.g., 2:1, the most common), while still others accept a wide range of external synchronizing impulses. The latter, which we required, typically are "high sensitivity" cameras rated to operate in 0.1 foot-candle minimum illumination. In acquiring one capability, therefore, the other was provided.

The synchronizing impulse is provided by a separate device, a "sync-generator", which will be discussed shortly. Some brands of cameras come with a built-in sync generator. Opting for this feature would have limited system packaging flexibility.

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Further in regard to sensitivity, it was necessary to assure that selecting a high sensitivity camera for low light areas would not limit camera use in brightly illuminated areas. Therefore, an upper range of 1500 foot-candles was required for operating outdoors in bright sunlight.

Camera resolution was established at a minimum of 500 lines, based upon requirements for direct ("live") observation, costs, and effects on other system components. Detailed monitoring of mechanical repair operations will require as much resolution as can reasonably be built into the system, and the 500 line minimum level is considered a reasonable trade-off point. Cameras that yield 700 lines are considerably more expensive than those in the 500 line range. Dropping below this level would be unnecessary, and would degrade performance of the monitors.

Viewfinders for the cameras were rejected as a requirement, since the camera will not be under continuous control. The only need for a viewfinder is in camera set-up. This can be accomplished using one of the small monitors.

Cameras were further specified as having a minimum signal-to-noise ratio of 40 db and being operable in either a random sync or external EIA standard sync mode. Video output was to be 1.4 volts peak-to-peak composite video 30 percent sync, with 75 ohm output impedance. All cameras were to accept standard C-mount lenses, and operate on 120 volts AC, 60 Hz power. Cameras were to weight less than 10 pounds; otherwise no size characteristics were critical. They were to operate in a temperature range from 20-110°F. and humidity to 95 percent. The cameras required automatic sensitivity control to adjust for light changes averaging up to 1000:1.

3.1.2 Lenses Lens selection was pivotal. The key to the high degree of flexibility required by this project was providing lenses which could adapt the cameras to a wide range of viewing conditions.

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Two remotely controlled lenses were specified, for use on two remotely directed cameras. These were high powered zoom lenses, suitable to be used in the pole climbing task. They provided a full-screen view of a 3 square foot target area at fifty feet. Two other zoom lenses (25-100 mm) provided flexibility for two additional cameras. Improved regular lenses were recommended for four other cameras, and a wide-angle optional lens was specified.

3.1.3 Monitors The number of monitors required is determined by the number of cameras, and the number of "preview" and "program" monitors required. Basically, two designs are possible. In the first, one preview monitor and one program monitor are used. The program monitor is used to show what is being recorded at any given time. The preview monitor is switched from camera to camera in order to observe or select signals for possible recording. Only one camera output can be seen at a time in the preview monitor.

In the second design, a preview monitor is provided for each camera, so that all outputs can be viewed continuously. A program monitor is used in the same manner for each of the recorders (and special effects generators) to show what is being recorded. This second design was selected, based on requirements such as that of the jet aircraft mechanic application. Here there was a need to continuously monitor activity at a number of testing stations. While a single monitor would have been less expensive, it did not provide the required capability.

Seven of the monitors were recommended to be 9 inch diagonal measure. This recommendation was based upon an analysis which indicated that the test administrator would be seated 2-3 feet from the screen. Optimum viewing distance (to take maximum advantage of the resolution capability) is five times the image height. A 9 inch diagonal screen is 5.4 inches high, so that optimum viewing distance was 26.6 inches. The program monitor for the recorders was likely to be located farther from the

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instructor, so a 17 inch monitor was specified, which provided an audio playback capability. This size yields an optimum viewing distance of 51 inches.

A resolution level of 600 lines was established to insure that the monitors would reproduce all of the resolution available from the cameras during direct observation.

Further specifications required that monitors should have a bandwidth of 9 Mhz, a minimum resolution of 600 lines at the center, and operate on 120 volts AC 60 Hz power. No audio capability or RF input was required on the 9 inch monitors; however, the 17 inch monitor was to have an audio amplifier and speaker, and be portable. Six of the 9 inch monitors were to be rack-mountable in a 19 inch rack, the other was to be portable.

3.1.4 Video Recorders As originally specified, the system used two 1/2 inch video recorders. Because no one existing item fully met the specification, that number was later changed to three. As specified, the system used two 1/2 inch EIA standard (7.5 inches per second) video tape recorders. They required a capability to record at both normal and slow (time-lapse) speeds, with normal, slow, and still frame play back. Slow speed recordings were to be capable of being played back at normal speeds to produce "fast" motion. They required a minimum resolution of 300 lines at normal recording speeds. The recorder was to accept one composite video input and provide an output of 1.4 volts. The minimum signal-to-noise ratio acceptable was 40 db. One microphone input and one line input was required. One line output required an audio response of 30 Hz - 5 KHz and an audio signal-to-noise ratio of 35 db. In addition, it was desired that the recorders have electronic editing capability, and provide for remote operation.

The basis for specifying a 1/2 inch tape recorder was a combination of cost and technical considerations. One inch machines produce high

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resolution, but they require more careful operation, are not as rugged or as simple to operate, and cost three to four times more than 1/2 inch machines.

The maximum resolution attainable with 1/2 inch machines is in the 300 line range. This is less than was available from the cameras, but recorded observations were only one feature of the requirement, and did not affect direct monitoring.

Since the utility of slow, fast, and stop action were to be evaluated, these features were also specified. The new EIA standard tape speed of 7.5 inches per second was specified to ensure compatibility across other standard machines. This feature is expected to be of increasing value in the future as such recorders become more common.

There are several other features that were specified as being desirable if they could be obtained without sacrifice. These included electronic editing and remote control. Current 1/2 inch machines offer various combinations of these features, but none offers them all.

3.1.5 Audio Equipment The audio systems specified were designed to serve in two specific applications, instructor training and jet aircraft mechanic testing. The requirements of these two areas were entirely different.

In instructor training, there was a requirement to pick up and record the continuous discourse of students and instructor, necessitating full room coverage. This might have been accomplished with one very expensive, centrally located microphone, which would have eliminated the need for a mixer. Such microphones are very delicate, and the cost would have exceeded that of the specified design.

A conventional design was recommended consisting of four area microphones for students and two fixed microphones for the instructor. These were fed into a mixer for input to the recorder. Cardioid-type microphones were selected to give wide horizontal coverage with a high front-to-back ratio, and to eliminate unwanted reflections.

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Response characteristics were specified for the microphones, which ensure adequate quality and intelligibility of voice recordings. The low impedance feature reduces noise in the cables, especially when longer cables are used. The sensitivity specified (-54 db) was to ensure pick-up of normal voice levels at an average distance of about 6 feet.

For the jet aircraft mechanic application, in contrast, a communication system rather than a recording system was required. A separate intercom system was therefore specified, to provide two-way voice communication between student stations and the video console.

3.1.6 Lighting Equipment Although high sensitivity cameras were selected to reduce the need for supplemental lighting, some fill and base lighting was anticipated as required when operating in areas of uneven light levels, such as in the hangar. A 600-watt incandescent lamp will give at least 12,000 lumens. This will illuminate a 27 square foot area with 125 foot-candles uniformly, assuming a utilization factor of $1/3$, which is realistic. These 125 foot-candles on a target having an average highlight reflectance of 50 percent, will throw about 4 foot-candles on a vidicon photocathode under the following circumstances:

Lens stop - $5/18$

Object distance - 40 times lens focal length

Lens transmittance - 80 percent

This is a worst case condition, i.e., with no light sources other than the lamp. Four foot-candles on a high-sensitivity vidicon is enough for a good image. Normally a lamp can concentrate its flux on smaller areas; usually there is ambient lighting. Therefore, enough light can be provided by a single 600-watt lamp to obtain optimum signals in most expected applications of the system.

3.1.7 Auxiliary Equipment A central synchronization signal generator was required to provide synchronous signals from the cameras and

ensure synchronous signal processing at all points in the system. Specified was a synchronization generator which would produce standard EIA sync, with vertical and horizontal drive and mixed blanking. It required an output of 4 volts peak-to-peak, operation on 120 volts AC, 60 Hz, and a size to fit in a rack panel of 3 inch height.

Special effects generators provide a capability to combine multiple camera images on a single screen, as in "split screen" pictures. Such devices can be obtained with a wide range of capabilities; the more complex ones are more appropriate to commercial production than video observation. It was desirable, however, to provide a capability to combine two signals in a single monitor presentation for recording or scoring. Specified were two special effects generators able to combine camera outputs split horizontally or vertically, with a variable field size.

One limitation of less expensive special effects generators such as those specified is that the overall size of the image cannot be reduced. If half of one camera output is being viewed, then only half of the total picture is available, not the whole picture in reduced size. This means that the camera may have to be repositioned to capture the specific detail of interest. Two of these devices were recommended for the system, to provide flexibility in combining camera shots and in feeding such signals to the two video recorders. They were required to produce output of 1.4 volts to a 75 ohm impedance, from 1.4 volt, high impedance input, and to fit a 3 inch rack panel.

Video switches permit flexible use of several cameras. They control which images are reproduced on which screens, and how signals are routed through the system. Pulse distribution switching amplifiers were specified to ensure constant strong signals throughout the system.

3.1.8 Mounting Equipment/Hardware Six tripod-type camera mounts capable of supporting 10-15 pounds, and two capable of supporting 20-25 pounds were recommended as basic camera mounts. In addition, the classroom area required two fixed, manually variable pan and tilt units that

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would support 10-15 pounds. Two medium duty remote control pan and tilt units with standard 355° pan and $\pm 90^{\circ}$ tilt capability were to be used for the remote cameras. The remote control panel was to provide control of the camera angle (pan and tilt) as well as of lens operation (iris, focus, and zoom); all modules were to be rack mountable. A console at least 40 inches wide was specified to mount six 9 inch monitors, controls, video switchers, pulse distribution amplifiers, intercom, and special effects generators. An additional rack, with wheels, was needed to carry the three tape recorders, one 17 inch monitor, and one 9 inch monitor.

3.2 SELECTION OF COMPONENTS

Based on the specifications just outlined, specific components available commercially were selected. Selection was made on the basis of minimum cost to meet specified functional criteria, and on compatibility when combined in a system. Minor adjustments of specifications were necessary. Table 2 (following on pages 39-49) lists equipment recommended in the Phase II project report (20 November 1972). Further changes were to be required in the course of procuring the equipment.

Table 3 (page 50) compares low-cost video tape recorders in reference to their varying capabilities. It will be observed that no one machine provide all the required features. This fact eventually led to procurement of two Javelins, for time-lapse capability, plus an additional Pansconic NV 3040 for its remote control capability.

TABLE 2. COMPONENTS RECOMMENDED FOR PROCUREMENT

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
4*	Cameras	GBC	CTC-5000		1650.00	Only camera in its price range that satisfies specifications, except for the tube, which does not have a separate mesh. But an actual performance test with another GBC camera that uses same tube and similar circuitry, gave very good quality images. One year guarantee. * QTY later raised to 8.
6	9" Monitors (Dual rack mounts)	GBC	MV-9Z (rack)	2 rack mounts	1180.00	Exceeds our resolution requirements. Compared to, e.g., the RCA PME-9, it has slightly more resolution; all operational controls are in front; price is about the same. Same guarantee as cameras. Advantages derived from having same brand as cameras, such as common parts, and having to deal with same service company.
1	9" Monitors (portable) with audio input	GBC	MV-9A (portable) with audio		295.00	Same as above.

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
1	17" Moni- tor (portable)	GBC	MV-17S (port- able)		368.50	Exceeds our specifications at a reasonable price. Provides audio amplifier and speaker. The rest of advantages mentioned for the 9" monitor.
2	Special Effects Generator	Dy- nair	SE-260A		1100.00	Simplest kind of effects generator available, and performs all necessary functions. Simple operation and small size.
1	Sync Gener- ator	Dy- nair	SY-290B		695.00	Provides EIA RS-170 sync, blanking vertical and horizontal drives. Small size.
2	Pulse Distribu- tion Ampli- fiers.	Dy- nair	PD-241		400.000	Meets specifications at low cost. Small size.

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
1	Video Distribution Amplifier	Dynair	DA-230A		200.00	Same as above. Advantage of having all video and sync accessories of the same brand, size and mounting requirements.
5	Video Switchers	Tele-mation	TVS-6X1B	Transformer for lights and 2 mounting panels Telemation RF-550	810.00	As opposed to other passive switchers available at same cost, provides 6 bridging inputs with looping connections. Frequency compensation built-in. 3 of them can be mounted conveniently on the same rack panel. Illuminated push-buttons.
1	Video Switcher 12x2	Dynair	VS-12x2CBL		Est. 700.00	Provides features needed for the output switcher, such as output isolation, bridging inputs and auxiliary switching.
2	Video Tape Recorder	Javelin	X-400		3990.00	Table 3 lists the important features of a selected group of recorders. To make the comparisons we have established four levels of importance for all the features, the following way: (continued on next page)

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
						EIA-J Type 1 Standard (most important) time lapse, stop action slow motion. Remote control, electronic cueing electronic editing (least important). As far as functional features are concerned, the Javelin X-400 and the Odetics TL500 are the most desirable of the group. However, it is anticipated that the quality of the visual in slow motion and stop frame in the Odetics is inferior to that of the Javelin because the Odetics uses two heads instead of four, and has variable slow speed. This was confirmed by the local dealer of Odetics, who was unable to provide a demonstration. We recommend the Javelin as a time lapse recorder.
2	Manually Adjustable Camera Mounts	Davis and Sanford	WB7		50.00	Very versatile, simple to adjust and low cost.

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
2	Tripods (light duty)	Quick-	7301 Set		188.00	Provides the system with movable mounts for fixed shots. Selection of brand is not critical except for availability of a variety of compatible pan heads.
2	Motion Picture (TV) Friction Head	Quick-	7201 Set		72.00	Has a handle. Can be used for fixed shots or for a second camera in the outdoors location.
1	Lo-hi Unit (light duty)	Quick-	7701 Set		41.00	Can give us views from a point as low as 5" from the ground.
2	Tripod (medium duty)	Quick-	5302 Set		430.00	Movable mount for remote-controlled pan and tilt unit.

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
2	Adapt- ters for Pan and Tilt Unit	Quick-	5561 Set		78.00	Allows the medium duty pan and tilt unit to be mounted on Tripod 5302.
1	Lo-hi Unit (medium duty)	Quick-	5701 Set		105.00	Same reason as for the light-duty unit, but to be mounted on the medium- duty tripod.
2	Remote Controlled Zoom 15-150 mm Focal Length	Pelco	TV-V10x15	1 Extender 2 -- (Cannon EX-2XA)	2565.00	Only model available that meets specification.
1	Fixed 9 mm Lens	GBC	914 Cosmi- car		199.50	Only model available that meets specification.

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TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
2	Manual Zooms 25-100mm	Canon	MV-4X25		700.000	Best available product
2	Pan and Unit (medium duty)	Pelco	PT-550 M		1160.00	Best available product
2	Remote Controlled Panel for Pan and Tilt Unit with var- iable speed, and room control	Pelco	PT-1500 PVX/LZ5	Cable D-409 50 Ft.	606.00	Best available product
1	Inter- com System	Tele- talk 6 speaker stations	1706A3	400 Ft. of Cable #1402	498.00	Units perform all the required functions at average room noise levels. They give an acceptable quality and intelligible sound. (continued on next page)

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
2	Lighting kits	GBC	LK-3		279.00	Provides 6 small directional lights with 6 stands that can be adjusted, to heights up to 10'. They come in a portable case which simplifies storage and transportation. This is simplest lighting available.
300'	Video Cable	Bel-den	8218		20.00	Small diameter at 75 ohms. Good performance at video frequencies.
15	UHF Connectors	Any brand, UHF type			15.00	Required accessories for the audio and video equipment. Brand of cables, connectors and stands is not critical, since most of them are satisfactory.
2	Mike Stands	Sony	MS-11	2 Adapters TM-1	58.60	

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
180'	Audio Cable	Sony Audio Cable		Adapters	51.00	Required accessories for the audio and video equipment. Brand of cables, connectors and stands is not critical, since most of them are satisfactory.
48	BNC Connec- tors	Any brand, BNC type			48.00	
		Male, straight				
4	Camera Sync Cables and Connectors				50.00	
1	Console for hangar equipment	Custom made		1 custom made mobile frame	850.00	

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TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
3	Front surface mirrors 15"x20"			Adjustable Mounts	145.00	Provide high fidelity reflection with minimum light loss.
Lot	Multi-contact connectors	Amphenol, several types		Belden 8218 Cable	270.00	Provide simplified installation procedure.
5	Microphone (cardioid)	Sony ECM-19B Electret Condenser			147.50	This model is the most sensitive of all the low cost microphones surveyed. It is more sensitive than most high quality microphones. A slight disadvantage is that this type needs a battery, but the battery has a 10,000 hours life (continuous duty) and it is a standard Type AA.
1	Microphone (cardioid)	Sony F-98 Dyna-mic			13.50	We needed a low cost medium sensitivity microphone for the instructor. Not critical.

TABLE 2. (CONTINUED)

QTY	ITEM	MFG	MODEL	ACCESSORIES	TOTAL COST	RATIONALE FOR SELECTION
1	Mixer	Sony	MX-12	1 Power Supply AC-12	120.90	This mixer is the only one that provides 6 low impedance inputs at this price level; of course, the response is not as wide as professional mixers have, but more than adequate for voice amplification.
20	One-hour one-half inch video tape.				600.00	Brand of tape will be somewhat dependent on final equipment selected.

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TABLE 3. COMPARISON OF VIDEO TAPE RECORDERS

	Time-Lapse Recording	EIA-J Standard	Remote Control	Electronic Editing	Electronic Cueing	Stop Action	Slow Motion
Sony AV3650	No	Yes	No	Yes	No	Yes	No
Concord VTR-850	No	Yes	Yes	No	Yes	Yes	No
Concord VTR-820	No	Yes	No	Yes	No	Yes	Yes
Concord VTR-800	No	Yes	No	No	No	Yes	No
Javelin X-400	Yes	Yes	No	Yes	No	Yes	Yes
Panasonic NV-8020	Yes	No	No	No	No	Yes	Yes
Panasonic NV-3020	No	Yes	No	Yes	No	Yes	Yes
Panasonic NV-3040	No	Yes	Yes	Yes	No	No	No
Slibadey SV-510D	No	Yes	No	Yes	No	No	Yes
Odetrics TL500	Yes	Yes	No	No	No	Yes	Yes

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SECTION 4.0 SYSTEM ACQUISITION

When the video monitoring system had been fully specified, URS/Matrix proceeded to acquire that system as hardware. This section describes the process by which it was acquired in its final configuration.

4.1 PROCUREMENT OPTIONS

Having specified a set of preferred off-the-shelf components, URS/Matrix had the task of assembling these components into a console with peripherals, and testing its operation. It was determined that this should be done by subcontracting to a firm which specializes in such work. Two reasons prompted this decision: first, such firms have direct contact with the myriad of suppliers who are involved in furnishing components for complex systems. Second, they have specialized facilities and resident talent, able to deal most economically with the problems which arise in mating components to form a complex system. That talent includes electronic technicians and engineers. Facilities include specialized work spaces, test equipment, tools, and on-hand supplies of cable, connectors and small parts. Matrix considered performing the work of systems integration directly, hiring in-house talent on a short-term basis, but decided that to do so would be expensive in terms of time and would risk unforeseen complications. In-house assembly can be recommended only for organizations having in-house shop facilities, and personnel with experience in video electronics.

Proceeding this way, an early question is at what point the subcontractor should be brought into the project. An important consideration in this decision is the amount of in-house video expertise available during preliminary design stages. In general, URS/Matrix feels that it is advisable to proceed as far as possible into technical design with independent resources, rather than to depend upon a contractor working from functional specifications. For this project, URS/Matrix had a video

engineer available to work and consult during the design phase. He provided the project manager with independent and objective guidance concerning technical feasibility of the functional options which were being considered.

When such advice has to be sought from potential contractors, their answers are often less than adequate because more careful analysis is required than they can afford to undertake prior to having a contract. Thus, the system designer can at this point find himself with a circular problem: The functional excellence of any system depends on specifying to the contractor a design which is technically feasible. This presumes design requirements which have been refined to the point at which all component interactions are known to be within the limits of technology. A vendor, however, cannot give the required level of attention to the problem until there is a contract. As a result, the system procurer may be unsure of the true technical feasibility of what he is attempting.

There are two ways of proceeding from this point. One is to have experts on hand (or to seek independent technical opinion by paying for it). The other is to choose the most reputable contractor available and let him "iron out the details", being prepared to make trade-offs during the process, to give up some desired capabilities, and to shoulder additional costs.

Since URS/Matrix had access to technical talent, it elected to take full advantage of it, and permitted the investigation of functional feasibility to proceed to the point of detailed system design and equipment capability specification. URS/Matrix may have proceeded too far into technical design, since contractors apparently are not accustomed to responding to this type of detailed specification. A description of the bid solicitation process will illustrate.

4.2 COMPETITIVE BIDDING

Our detailed design specifications were sent to contractors to solicit competitive bids. The apparent result of providing such detail was that

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the overall system concept was not readily apparent to potential bidders. Eventually the system had to be discussed and explained directly to each of the interested bidders. This condition resulted primarily from the uniqueness of the system concept, and preconceptions which bidders had as a result of their familiarity with more conventional systems.

Once the function and specifications had been explained, the number of bidders decreased. Bidders must be able to estimate reliably both hardware costs and the amount of labor which will be required to assemble a system and to be sure that it works as specified. Not many companies were ready to enter fixed-price contracts that required them to deliver a fully functioning system. They were willing to propose equipment costs and labor rates for system assembly, but not a firm fixed-price quotation. It apparently is not customary for such firms to respond to someone else's design. Several questions were raised by bidders which indicated their belief that, because of the completeness of design specifications, some other firm must have done the design and that we were soliciting only token competitive bids. Obviously, few firms would bid under such conditions. Only when they were assured that the design was done in-house, and that all bids would in fact receive equal consideration, were we able to attract multiple bids.

Considering the way in which video equipment vendors operate, competitive bidding does not seem to be the most useful approach to system acquisition. This is most particularly true when there is great reliance on the system assembler for technical design advice. If one is interested primarily in equipment, and in relatively few or single services, then competitive bidding may be a more useful procedure.

Once the detailed functional and technical description was communicated to the bidders, they each proceeded to respecify the system in their own format and conventions. Apparently this was one of the problems with the drawings which we provided; at the shop and detail level there is a certain variability in the conventions and assumptions used. To some

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extent our analysis resulted in a design which was too detailed, in that it had to be restated in the vendor's terms. Had we been able to identify the vendor sooner we might have saved some of this time and energy.

On the other hand, before we went to the vendors we had made certain that what we were proposing to do was technically and commercially feasible, using currently available components. In preparing systems of unique design, more is required than a cursory analysis of the requirement and of possible solutions. Someone has to pay for this - either the original analyst or the vendor. The more completely the analyst has proven feasibility and the more equipment independence he has achieved, the higher the probability that he will achieve a solution which is optimum to his original concept, and unconstrained by the limitations or preferences of the vendor.

If competitive bidding is not satisfactory, how should a video contractor be selected? There are several considerations, not vastly different from those for selecting any other kind of contractor. First, the contractor must have sufficient staff and talent to ensure his ability to perform the work. Then he must show evidence that he grasps the problem you are presenting, and is able to suggest viable solutions. Experience and reputation are other important indicators, and the best way to judge these is to review his work for prior clients, and if possible, discuss his work with them. Applying this type of scrutiny to the available video contractors will reduce the field of available choices to a manageable number very readily.

4.3 ACQUIRING THE SYSTEM

We have described difficulties encountered in subcontracting for procurement and integration of the video system. The impact of these perturbations in the contracting process was to prolong the period between system design and system fabrication by approximately 3 months. The intervening time was spent in soliciting, explaining, clarifying and negotiating. In retrospect, we believe that this time loss could have

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been reduced if the contractor had been chosen on a basis other than cost quotation, and had been brought into the project at an earlier stage to work with our in-house technical personnel. Doing so would have reduced system design expense by eliminating duplication in detailing the design, and by saving the time required to review and clarify the system with a multiplicity of bidders.

Again, we are speaking of a system unique in design and functional concept, as contrasted to systems which may have been repeatedly made before. The considerations raised would be even more forcefully relevant to any system which employs specially designed or modified equipment. While we focused, in this project, on off-the-shelf components, there were several points at which it would have been desirable to modify component capabilities, or to have a special purpose item built. Such actions could be expected to add considerably to the time and effort spent in system development.

The contract which was eventually let for the system specified the equipment to be purchased, the fundamental capabilities required of the system, the general console configuration (by a drawing), the costs to include all labor and equipment, and a delivery schedule. The main time consideration for the contractor was that which would be required to acquire components from manufacturers and suppliers. In the system there are approximately 100 line items, which had to be secured from numerous different sources. The contract called for delivery of the system in 90 days. It took the first 60 days for the contractor to receive enough materials to begin. At 90 days the system was 90 percent complete, but delay in delivery of several key components delayed completion of the system for approximately an additional 30 days.

As soon as the system was sufficiently assembled to permit meaningful appraisal of the physical layout (at about 75 days), but while changes could still be made without causing major setbacks, the designers took a careful look at its configuration. This procedure is highly recommended, since it provides the opportunity to correct oversights or make adjustments in design. At the time this review was made, most major components

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were in position but were not interconnected or functioning. Several changes were made as a result of this review. For example, panel doors were modified for better access to connector panels, controls were shifted around, the top row of video monitors was tilted forward 30° for improved visibility, and casters were added to the consoles. These changes improved system operation and transportability.

Another physical review of the system was held at the time originally scheduled for completion, as had been stipulated in the contract. Its purpose was to verify that all the required functional capabilities of the system were present and operational. Checks were made of capabilities such as being able to inter-record between VTR's, to combine cameras on the special effects generators, and to record inputs from the sequential switcher. Individual components were verified as being in good working order. This system review had to be conducted in part by using some borrowed equipment in place of components which had not been received, but it demonstrated that all functional requirements were met. On the other hand, it demonstrated that there were problems remaining in electronic alignment of the components, some cables to be bundled, and other minor problems to be taken care of prior to arrival of the remaining equipment.

A third check of the system was made at the time of completion and preparation for shipment. The purpose of this check was to verify that identified problems had been corrected and to inventory the equipment for shipment.

In addition to performing these system checks, URS/Matrix personnel were in frequent telephone contact, resolving questions such as recommendations from the contractor for more efficient interconnection of equipment or substitution of an alternative brand of component. A member of the URS/Matrix staff spent time at the contractor's facility during set-up for the functional tryout, to learn how to set up and adjust the equipment. Such close contact during equipment fabrication is necessary, and is recommended. The contractor must, of course, clear every alteration

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or change from the approved plan with the system designer so that the impact of any change can be evaluated on such parameters as cost, function, and time. Only under this condition can the designer be confident that the final system will meet his original intent as closely as possible.

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SECTION 5.0 DESCRIPTION OF THE VIDEO SYSTEM

Section 3.0 detailed the process by which technical specifications for the video system were developed, and outlined those specifications as they existed prior to procurement of the equipment. Section 4.0 described the processes of integration of components into a system, and acceptance testing. In the course of these actions, certain minor changes were necessary in system configuration and selection of components. Those changes were required as the result of problems of component compatibility, and failures of certain components to conform with advertized specifications. At the same time, minor improvements in system configuration and capability were recognized as feasible at no significant cost, and were incorporated.

This section describes the system, in operational terms, as it was finally delivered and now exists (December, 1973). The role of certain features in accomplishing program objectives will be discussed.

5.1 SYSTEM CONFIGURATION

The experimental video system was designed to provide a means for investigating questions concerning the application of video technology to technical training, according to the rationale described in Section 2.0. It was designed specifically for application in the three training environments specified in Section 2.0; in addition it was designed to offer maximum experimental flexibility in further study and development, elsewhere in the USAF technical training environment.

The design concept was that of a system flexibly adaptable to video monitoring and recording of student performance in training. It was designed as an experimental tool, to be used in developing techniques for video in testing and performance monitoring. For these reasons, the

system was designed so that it could easily be assembled in special configurations suited to particular research or training tasks.

During the study of USAF practice described in Section 2.0, three specific USAF training activities were selected as initial points of application. The system will be described in terms of the three configurations finally used during those on-site system tests. Treated first will be the system as it was applied, in its fullest configuration, to study jet aircraft mechanic performance testing.

5.1.1 Full System Configuration (for Jet Mechanic Area) This application employed all components and subsystems of the video system. Major components are:

Eight video cameras, two remotely controllable, which can be positioned at selected testing positions.

Two time-lapse video tape recorders, which offer options of standard, speeded, slowed, and stop-frame playback. One remotely controllable video recorder. (Only two of the three recorders can operate at any one time.)

An audio recording system. Six microphones, input to two audio mixers, for output to video recorders.

A sequential switching device, which permits the output of up to four cameras to be displayed on one monitor.

Two special effects generators, to combine up to 4 input channels as split-screen displays.

Continuous video monitoring for four cameras (four monitors). Sequential or manually-switched monitoring for four other cameras (one monitor). Continuous monitoring of the output of each special effects generator (two monitors). Continuous monitoring of two recording channels (input or playback) (two monitors).

A two-way push-to-talk intercom system for communicating between the system console and the testing stations.

A central control console. Figure 1 is a representation of the control console.

5.1.2 System Configuration for Power Lineman Area In the power lineman field test, only a portion of the equipment was required. For this reason the full system was designed to permit needed components of

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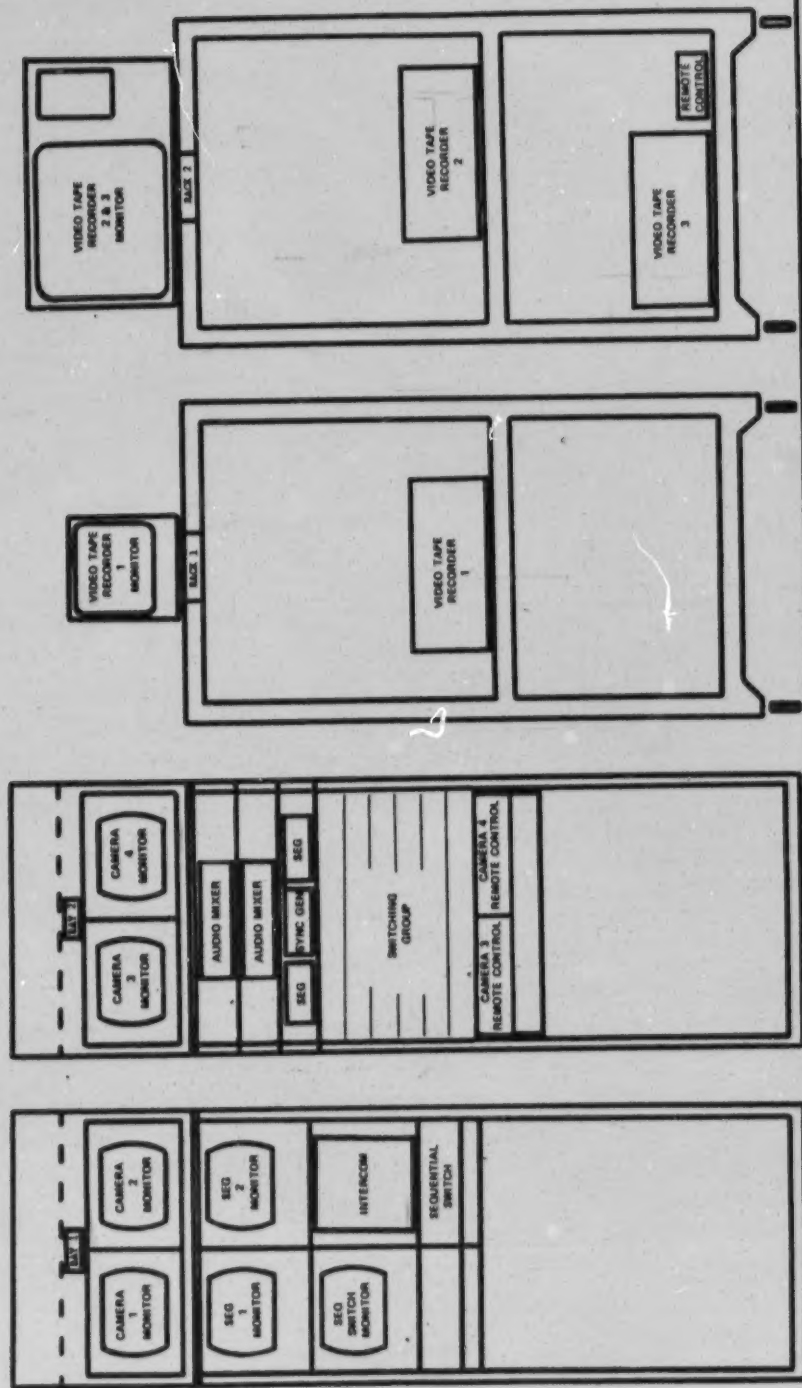


Figure 1 - Full Equipment Console

the equipment to be extracted, and used in a simpler independent configuration. This break-out feature makes transportation to a remote area easier. Including such a feature in an experimental system resulted in increased design and development costs; an operational application, on the other hand, would use only the simpler configuration, and achieve a lower equipment cost. The major components used in this configuration were:

- Two remote control cameras used to track students climbing poles.
- Two recording channels, one with a special effects (split screen) capability.
- Monitors dedicated to each camera.

Figure 2 shows the arrangement of equipment and controls on the mobile console.

5.1.3 System Configuration for the Instructor Training Area The concept employed in the instructor training field test differed significantly from other applications. In that test, the system did not have an operator. It was designed so that the student instructor could activate the system at the beginning of his presentation, and shut it off at its conclusion. The tape could then be reviewed at any subsequent time. During the experimental evaluation period, URS/Matrix research personnel were present to set-up, adjust, and monitor the recording process. Major components employed in this application were:

- Two fixed position cameras, one facing the instructor and the other fixed on the students.
- Two recording channels, one with special effects capability.
- Multichannel audio input to record both instructor and student audio outputs.

The console configuration used for this application will be the same as that used in the power lineman area (Figure 2).

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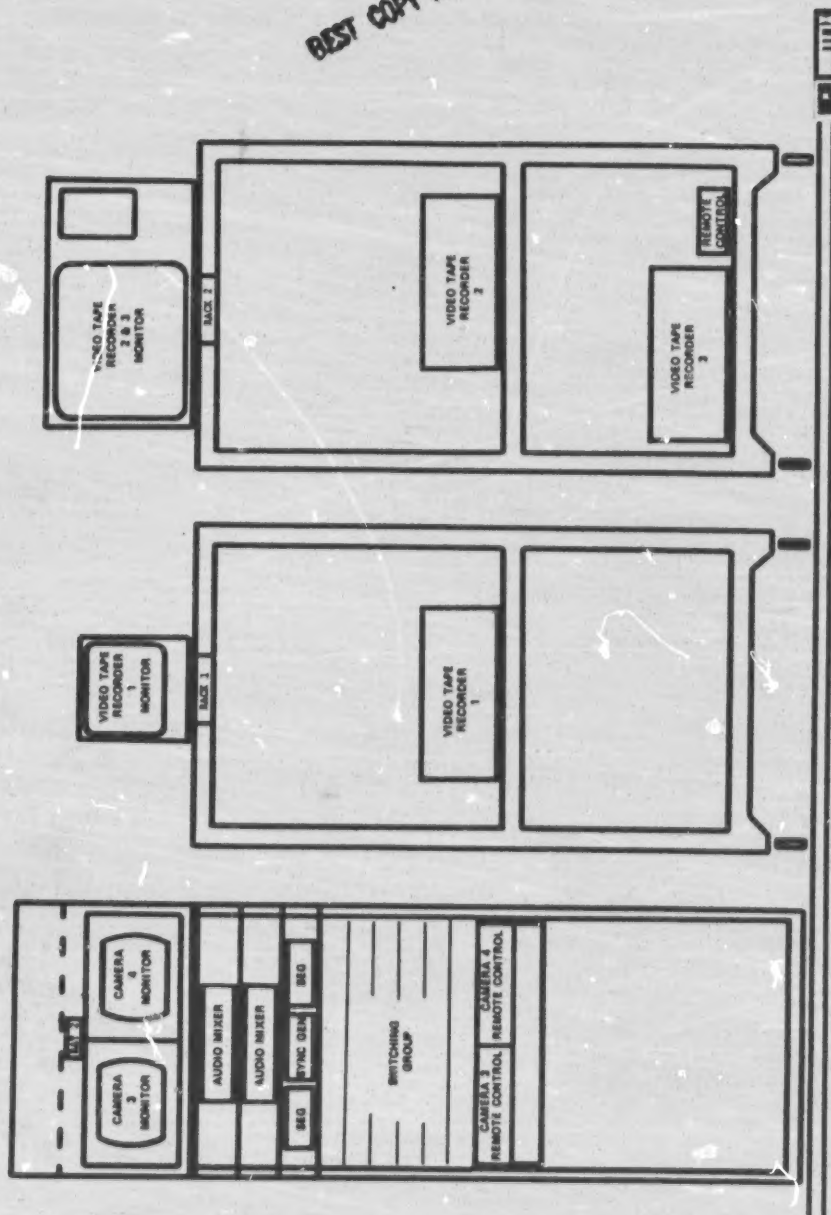


Figure 2 - Partial Equipment Console

5.2 APPLICATION OF SYSTEM FEATURES

Table 4 is a tabulation of system features, in terms of the context in which they were experimentally applied, with their expected utility. We might theoretically have wished to apply and evaluate each feature in all applications. However, training environments are highly diverse; each application presents unique requirements for monitoring and measurement information, but no application requires all features. Precisely for that reason the system was developed to provide greater experimental flexibility than is required for any one application.

As can be seen from the table, the hangar area - jet mechanic application - offered the widest range of opportunity for examining systems feature utility.

On the other hand, the power lineman test permitted studying the utility of video to monitor an otherwise inaccessible task performance, and to apply speeded playback. Similarly, the instructor training application permitted study of "operator free" use, and use of recorded sound.

5.2.1 Time-Lapse Recording "Time lapse" video recorders offer a capability to play-back action at fast, normal or slow speeds, and in stopped-frames. The particular recorder used is Javelin model X400, which can be used in the following modes:

Standard

Recording at standard speed of 7.5 tape-inches per second with play-back at standard speed produces a standard video presentation of 30 frames per second. Tape reels can be obtained in either 30 or 60 minute lengths.

Slowed Motion

Recording at standard speed and playing back in LONG PLAY produces a slow motion effect by reducing action to 1/7th normal speed.

Long Play

Recording at LONG PLAY speed and playing back at the same speed, the

TABLE 4. SUMMARY OF SYSTEM FEATURES

SYSTEM FEATURE	APPLICATION AREA	FUNCTIONAL CONTEXT	UTILITY
Time Lapse Recording	Jet Mechanic Power Lineman	Task Quantifications Recorded Evaluations	Analysis of actions; rapid location of tape sequences; Review of performances
Remote Camera Control	Jet Mechanic Power Lineman	Recorded Evaluations Live Observation	Provides operator control over camera to permit rapid repositioning
Special Effects (Split Screen)	Jet Mechanic Power Lineman Instructor Training	Recorded Evaluations Live Observation	Will provide combination of two views of same or different actions on a single screen
Remote Recorder Control	Jet Mechanic Power Lineman	Recorded Evaluations	Provides for locating recorder controls with other system controls
Sequential Switching	Jet Mechanic	Live Observation	Permits display of multiple actions on single monitor in automatic sequential format
Multiple Cameras/ Monitors	Jet Mechanic	Live Observation	Provides for coverage multiple test stations simultaneously

TABLE 4. (CONTINUED)

SYSTEM FEATURE	APPLICATION AREA	FUNCTIONAL CONTEXT	UTILITY
Mirrors	Jet Mechanic	Live Observation	Provides visual access to confined work spaces
Interim	Jet Mechanic	Live Observation	Provides exchange of instructions/questions from console to student stations
Audio Record	Instructor Training	Recorded Observation	Records instructor and student verbal exchange

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equipment records only 5 frames per second as contrasted to the normal speed of 30 frames per second. Thus, the viewer sees a slightly jerky or discontinuous motion. Tape is conserved, and 7 hours of video can be recorded on a standard 1 hour tape.

Accelerated Motion

Action recorded at slow LONG PLAY speed and played back at standard speed is seen as accelerated motion, 7 times actual speed.

Stop-Frame

Action recorded at either speed can be stopped, the equipment then replays the same frame as long as may be needed. In addition, the Javelin recorders are equipped with a special control for advancing the tape manually from one frame to the next.

The utility of this capability was examined in several contexts. In the task quantification process, it was anticipated that the slow and stop motion features would be useful when identifying criterion evaluation points and when examining performance sequences. The speeded motion capability was used experimentally as a means of efficiently sorting through quantities of recorded performance in order to find criterion sequences. It was of interest to determine which types of task could be followed and interpreted during speeded playback, and which could not.

5.2.2 Tape-to-Tape Editing The video system has two recorders available to permit tape-to-tape transfers. Thus, when material has been reviewed and evaluated, selected portions can be compiled onto a new tape.

5.2.3 Remote Camera Control A remote control capability (azimuth, elevation, focus, iris and zoom) has been provided for two of the cameras in the system. The primary benefits offered are camera savings, operator savings, and an ability to track or observe actions not otherwise monitorable. In the jet mechanic area, remote control made it possible for

a single camera to pan to two or more test positions. Where a camera operator might otherwise be required, it made it possible for instructors at the console to perform adjustments needed to track subject motion, to frame pertinent action and to focus for close-up shots. In the power lineman area, a remote camera was essential, since fixed cameras could not track a man climbing a pole. Considerable operator loading costs are imposed by remote cameras; the benefits must be assessed in terms of those costs.

5.2.4 Special Effects Generator The special effects capability to combine two images on a single screen was employed in several ways. In the jet mechanic area it was used during live observation to provide two views (i.e., a close-up and an overall view) of a given operation and to put views of two different operations on a single screen. It was employed in the same manner in the power lineman application. In the instructor training application, the split screen was used to combine a synchronized display of two views, instructor and students. It might further be employed to insert a meter, clock or scope display adjacent to subject performance, or to compare a criterion and a test performance side by side.

There are several known difficulties of split screen displays which were examined. The first is that the special effects generator splits a camera's picture in two, rather than providing a reduced version of the whole picture. This had implications for camera positioning to insure capturing the desired detail. A second drawback is that the special effects generator degrades the picture signal somewhat. This is especially critical when that signal is to be recorded, since recording produces further loss of net resolution.

5.2.5 Automatic Tape Indexing In collecting any significant amount of data on video tape, it becomes a considerable task to keep track of the points on tape at which specific events are recorded, and an even greater task to retrieve those data in any order other than that in which

they were originally recorded. For these reasons, an optimum system would be one which offered an automatic means of logging recordings, and relocating them at their tape addresses. In the absence of such a capability, the conventional practice is to keep a written log, identifying discreet sequences by tape number, with locations on tape shown by an index counter or footage meter. This practice is cumbersome, and imposes a high operator-time load.

No ideal capability of this kind exists or can be economically assembled. As an alternative, a Panasonic VTR model NV 3040 was identified, and procured as a third VTR. This VTR has two features to assist in relocating specific sequences. The first of these is a mechanical device associated with the index counter on the recorder. When this device is engaged by setting a switch, the recording will automatically rewind to the zero position. Zero can be set at the beginning of the tape, or at any other tape position. Since the recorder is equipped with a remote control, an instructor-console operator can simply press the rewind switch and continue another task while the recorder returns to the chosen (zero) setting. If, in recording or reviewing a tape, the operator observes an event which he will want to review, he resets the counter to zero at that point, and when he rewinds the recording will stop at the same point. This capability is limited because it provides only a temporary index, only one address, and that address can be reached only by rewinding, not forward searching.

Multiple indexing is potentially possible with this recorder, but would require additional equipment, as well as manually inserted metallic foil sensors on the video tape. Because the tape transport is electrically (not mechanically) controlled, it lends itself to automatic control systems. The manufacturer now furnishes an adapter which will control play and rewind between any two marked points on the tape. This feature is not a practical method for marking multiple addresses on the tape in USAF applications, and therefore, it was not acquired for the system. It can be added in the future, if desired, or electronics might be fabricated to provide a less cumbersome search-and-stop capability.

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In any case, such a capability depends on a remote-controlled (electrically controlled) transport deck. The Panasonic recorder was procured for the system because of its return-search capability, its potential for adaptation, and its remote control capability which will be discussed in the following section.

5.2.6 Remote Recorder Control A problem in applying video techniques is the load imposed on the user by recorder operation. Due to limitations in off-the-shelf technology, the video system is less than optimum in this respect. Time-lapse recorders were not available with remote control, so for time-lapse recordings an operator must physically go to the recorder and manually control each operation. An alternative is offered by the Panasonic recorder, which can be controlled by a remote-control keyboard. For reasons of system flexibility these controls were not built into the console, but they can be located within the immediate area for easy access by the operator.

5.2.7 Sequential Switching A sequential switching device is provided, which controls the outputs of four cameras (numbers 5-8) to a video monitor. This switch can be controlled to select one to four cameras in sequence, each for a standard interval controllable from 1 to 58 seconds. Alternatively, it can be used as an electronic switch, to select the output of any one camera for uninterrupted display. This feature was employed in the jet mechanic tests as an alternative means of monitoring student performance. It was not used in the other applications, since they employed only two video cameras.

5.2.8 Cameras and Monitors The multiple camera and monitor capability is designed to permit study of the range of operations which can be monitored simultaneously by an instructor under different modes of live observation, recording, and mixes of the two. In combination with the sequential switching device discussed previously, it also permits examination of full-time versus sampling display techniques.

5.2.9 Mirrors Mirrors were used in the jet mechanic test to provide visual access to student performance. This area is the only one which contained severe access problems.

5.3 OPERATING THE SYSTEM

An objective of this project was to design the video observation system so that it will augment instruction without requiring numerous additional personnel or imposing self-defeating operational loads on an instructor. This subsection describes personnel workloads imposed by the system in terms of specific control operations. In general, the system is designed to be operated and controlled by one instructor-operator, without additional operators either at the cameras or at the console controls. Using the system will require time and attention, at the expense of other instructional duties. The hope is that in any application a total saving of time will result, as compared to gathering the student information concerned by alternative, non-video, means. In some cases, information can be acquired which is not available by any conventional means.

The instructor-operator who is referred to in the following paragraphs is the console operator just described. He will be variously referred to as an operator or an instructor, depending on the task being described.

As has been observed before, the video observation system was designed to incorporate a wide range of capabilities in monitoring, signal processing, recording and display of audio-visual data. This range of capabilities is used to adapt the system to widely differing needs in training and human measurement. For any one application, not all capabilities of the system are required. The system is therefore designed so that, by switching, its various components can be flexibly interconnected to fit the needs of any task at hand. It is possible, furthermore, to use the system in less than its fully physical configuration.

For instance, a particular project may require only one camera and recorder, in which case only one camera, one bay and one rack need be transported and set up in the project area.

Figure 3 represents the console (bays and racks), set up in its fullest configuration, with notation of the location of functional areas.

5.3.1 Functional Areas in the Control Console The console consists of two bays and two racks. It houses the principle components other than cameras, and provides the control, monitor, switching, recording, and display capability by which flexibility is achieved. The major components are:

At (A) in Figure 3, monitors which continuously display the outputs of cameras 1 through 4, and indirectly display outputs of cameras 5 through 8.

At (B), a two-way push-to-talk intercom system for communicating between the system console and student stations.

At (C), controls for remote adjustment of the two remotely controlled cameras 3 and 4.

At (D), a sequential switching device, which permits the output of up to four cameras (5 through 8) to be displayed on one monitor (marked (A,D)).

At (E), two special effects generators, to combine up to 4 input channels as split-screen displays.

At (F), a switching group by which connections are made between the components shown.

At (G), three video tape recorders. Two VTR's which offer options of standard, speeded, slowed, and sto-frame playback, and one remotely controllable VTR. (Only two of the three recorders can operate at any one time.) Two monitors display what is being recorded or played back.

5.3.2 Cameras The video system provides eight cameras, of which six are fixed-position type and two are remotely controlled.

All cameras can be moved about on their tripods within a distance of 65 feet from the console (the length of their cables).

The fixed-position cameras are most effectively used where the target area can be pre-defined, and when the focal length of the subject within that area does not shift significantly.

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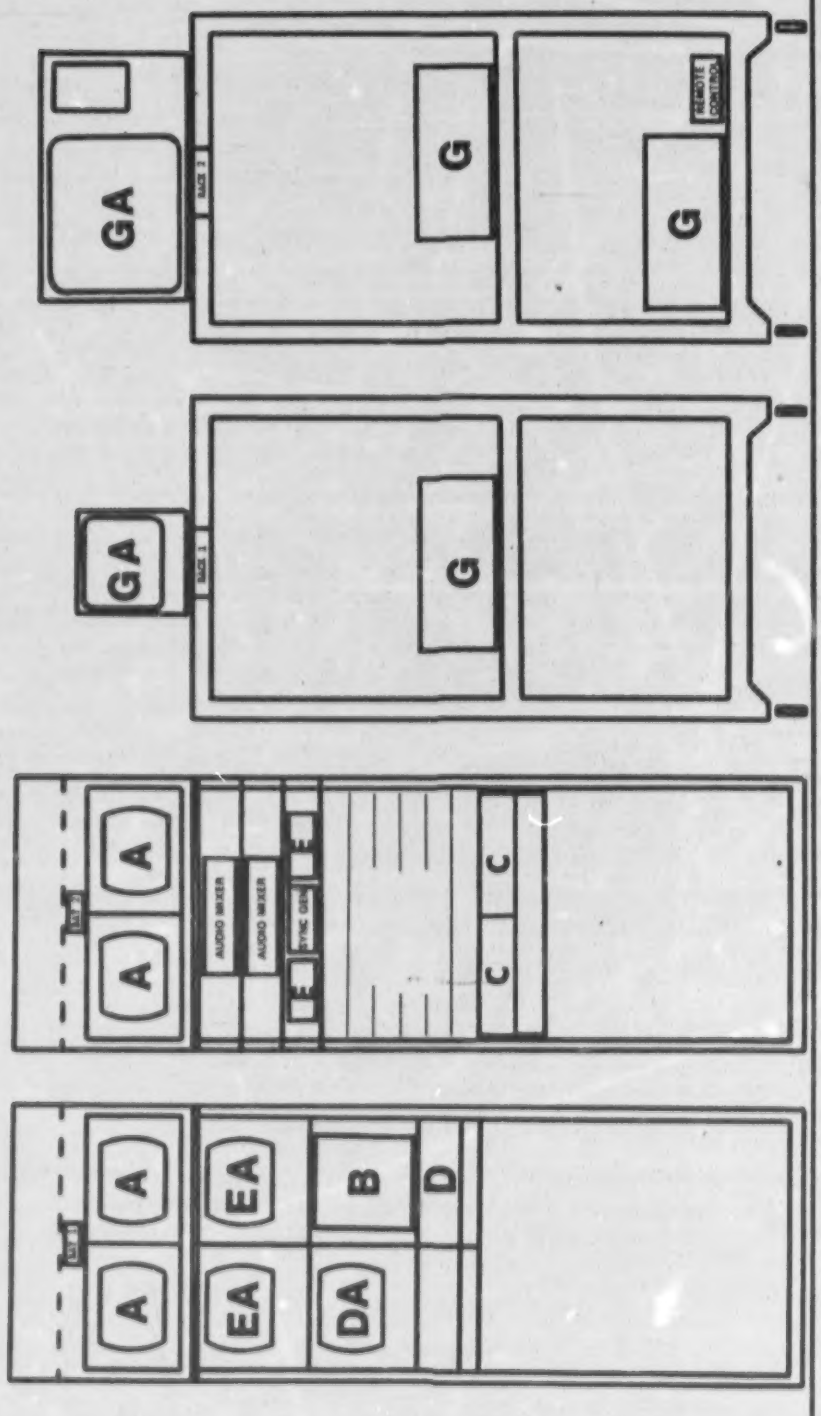


Figure 3 - Location of Functional Areas

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The remote control cameras can be controlled from the console in pan (horizontal azimuth) tilt (vertical elevation or depression) zoom, focus, and iris opening.

Outputs of cameras 1, 2, 3, and 4 are displayed at the top monitors of Bays 1 and 2 ((A) in Figure 3)...

Outputs of cameras 5, 6, 7 and 8 go first to the sequential switch ((D) on Figure 3), and then are displayed, one at a time, on the SEG monitor (A,D) in Bay 1.

5.3.3 Sequential Switch Outputs of cameras 5 through 8 enter the console through the sequential switch in Bay 1, marked SEQ on Figure 1, and illustrated in further detail by Figure 4. This switch selects one camera at a time, displays that video signal on the monitor to the upper left of the switch, and makes the signal available at the switching group for further use.

The "sequence" toggle switch (Figure 3-3) controls the mode of operation of the SEQ. When it is set on "manual", sequencing of the switch is controlled by pressing the "manual" push button switch: Each time that button is pushed, the switch will turn to the next camera, in sequence by number from camera 5 through 8, 7, 8 and then back to 5. When switched to any camera it will remain in that setting until the "manual" button is pushed again (or until the toggle switch is set to "auto". See following.)

One of the channel indicator lights is lit at any time, and indicates which camera is currently selected. Lights 1 through 4 represent cameras 5 through 8, respectively. Lights 5 and 6 are inoperative.

When the sequence toggle switch is set at "auto", the switch automatically changes cameras after a fixed interval which can be varied from approximately one to approximately sixty seconds. In other words, at this setting the switch will connect and display on the SEQ monitor first the output of camera 5, then that of camera 6, then 7, then 8 then back to 5, indefinitely.

The "time" knob controls the number of seconds that each camera is displayed, from one to about sixty seconds.

The "camera in" knob can be used to control the number of cameras being monitored. With the setting at "4", all four cameras (numbers 5 through 8) are selected in sequence. Turned back to "3", camera 8 is dropped and the switch cycles from number 5 through number 7 and back. Turned to "2", it alternates cameras 5 and 6, and at "1" it will select only camera number 5. Positions 5 and 6 are inoperative.

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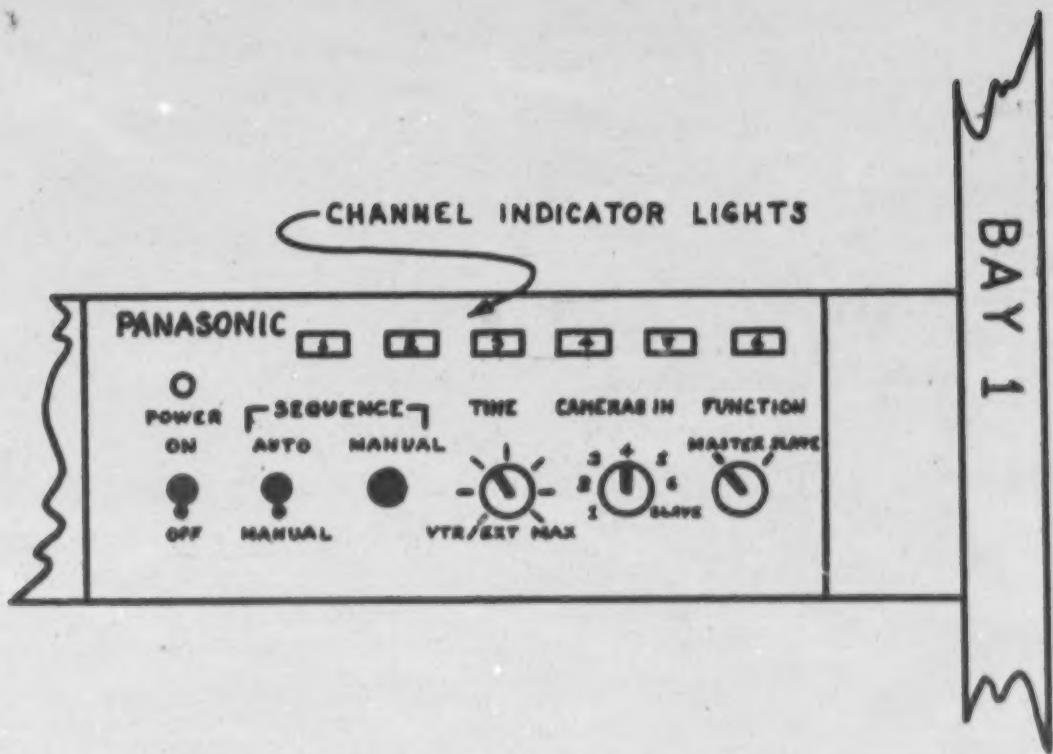


Figure 4 - Sequential Switch Controls

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The "function" switch is inoperative, and will remain set on "master".

To summarize: The SEQ controls video input from four cameras (numbers 5 through 8) to a video monitor and to the console. This switch can be controlled to select one of four cameras in sequence, each for a standard interval controllable from one to sixty seconds. Alternatively, it can be used as an electronic switch, to select the output of any one camera for uninterrupted display.

5.3.4 Synchronization Signal Generator In Bay 2, centered above the switching group, is a synchronization generator, marked SYN in Figure 1. It operates continuously and provides synchronization signals to other equipment. It requires no control or adjustment except to observe that the pilot light is on.

5.3.5 Special Effects Generators Two special effects generators are located in Bay 2, one on each side of the SYN and over the switching group (marked "SEG" on Figure 1).

Each SEG has a capability to combine the outputs of two cameras into a single video picture output. It can split the screen horizontally or vertically, or insert one picture into the corner of another; the position and size of the insert can be freely varied. SEG outputs are displayed on the SEG 1 and SEG 2 monitors, in Bay 1.

To operate a SEG it is necessary to first select two cameras for input, and connect them to the SEG using the switching group (as described in paragraph 5.3.6). One camera - the one selected on the upper switching panel, can be regarded as forming the basic video picture, while the other, selected on the lower switch panel, can be regarded as an insertion onto that picture, replacing one corner of the picture on the monitor tube.

The second picture is "wiped" onto the first from one of the four corners. Select a corner to be used for insertion, and set the function switch at the far left (Figure 5) to point toward the circle the corresponding corner of which is darkened.

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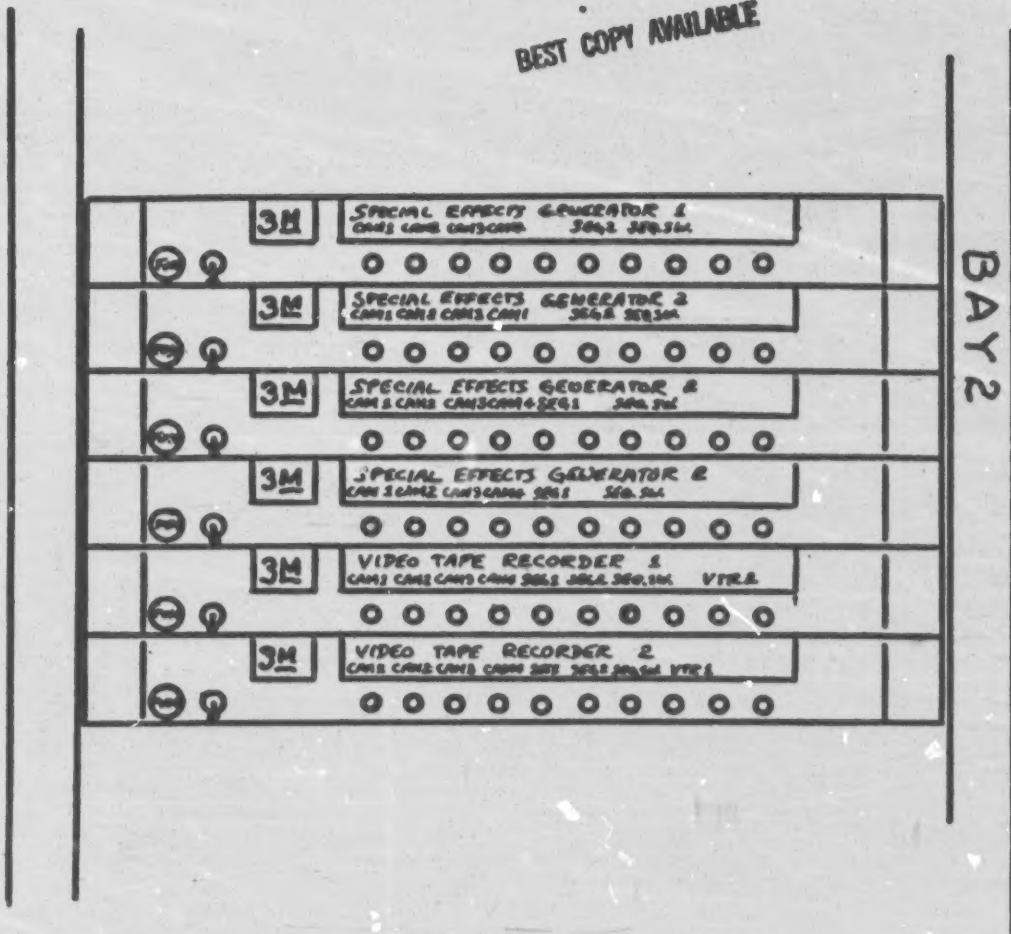


Figure 5 - Special Effects Generator Controls

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The monitor now displays the basic video picture, with a portion of the second video picture inserted at one corner as a quarter-screen display.

If only one picture appears, it is necessary to adjust H and V WIPE (see below).

The operator sets the horizontal wipe control (H WIPE) to move the lower edge of the inserted picture up or down - in other words, to control the position of the line dividing one camera input from the other horizontally. By turning H WIPE all the way to the left, the inserted signal can be wiped completely off the screen. By turning it all the way to the right, the SEG is made to produce a split-screen display, on which the two camera outputs are displayed to the left and right, divided vertically.

The operator sets the vertical wipe control (V WIPE) in a similar manner to control the vertical line dividing the two camera signals. By turning V WIPE all the way to the right, the SEG can be made to produce a split-screen display divided top and bottom, horizontally.

The inserted signal and the basic signal are both centered, in the SEG display, in relation to the whole monitor tube and not in relation to the portion of the picture field which they occupy. Therefore it usually is necessary to realign the cameras in relation to their targets, so that the significant target detail is off-center to each camera, but centered in relation to that portion of the monitor tube on which the camera output is displayed. This is a major cause of operator work load in using the SEG.

Using the switching group, it is possible to connect the output of one SEG as input to the other, and thus combine 3 or 4 cameras in a single SEG display. Some degradation of video signal occurs when SEGs are cascaded in this manner.

5.3.6 Switching Group The switching group on Bay 2 (SWITCH GP on Figure 1) consists of six switch panels, each of which controls the inputs

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to a SEG or a Video Tape Recorder (VTR). Figure 6 shows those switches in detail. Collectively, they make it possible to route signals from the cameras in a variety of ways for video display or recording.

Figure 7 is a block diagram of the video observation system and illustrates how it can be connected. The switching group is represented by the box-tailed arrows at the center. Each vertical arrow represents one switch panel (seen horizontally on Figure 6), with its output at the bottom. Each X represents a push-button on that panel, by which one input at a time can be connected into the switch. Horizontal connecting lines across the switching group represent continuously connected bus lines, which carry the outputs from cameras, SEGs or VTRs, and connect them to monitors each of which continuously displays the signal carried on one bus line. When the button at X is on, the bus line is connected into the switch.

Note at the left (Figure 7) the eight video cameras. Cameras 1 through 4 connect directly to fully committed monitors, and can each be further connected by push-button switching to an input of SEG-1 or SEG-2, to VTR-1 or VTR-2 or (by plug-in connection), to VTR-3.

Any one camera can be connected to more than one output device at the same time: i.e., Camera 1 to SEG-1, SEG-2, VTR-1, and VTR-2. But camera 1 (for instance) could be connected to both inputs of either SEG. (There would be little point in doing so. Two cameras are necessary to form a special effects display.)

Cameras 5 through 8 go first into the SEQ (reference paragraph 5.3.3). The output of those cameras is displayed, as the output of the SEQ, one camera at a time, on the SEQ monitor. The output of the SEQ can be connected through the switching group to either input of either or both SEGs, to VTR-1, or to VTR-2 or 3. Because the SEQ selects only one of cameras 5 through 8 at any time, there is no way that two of these cameras can be used or monitored simultaneously.

The outputs of SEG-1 and SEG-2 are continuously displayed at the SEG-1 and SEG-2 monitors. Those outputs can be connected as inputs to the other SEG, or to any VTR.

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IDENTICAL UNIT SEG 1 AT
LEFT SIDE OF BAY

BAY 2

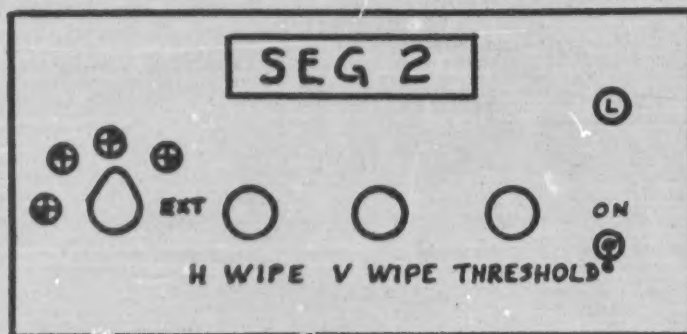


Figure 6 - Switching Group

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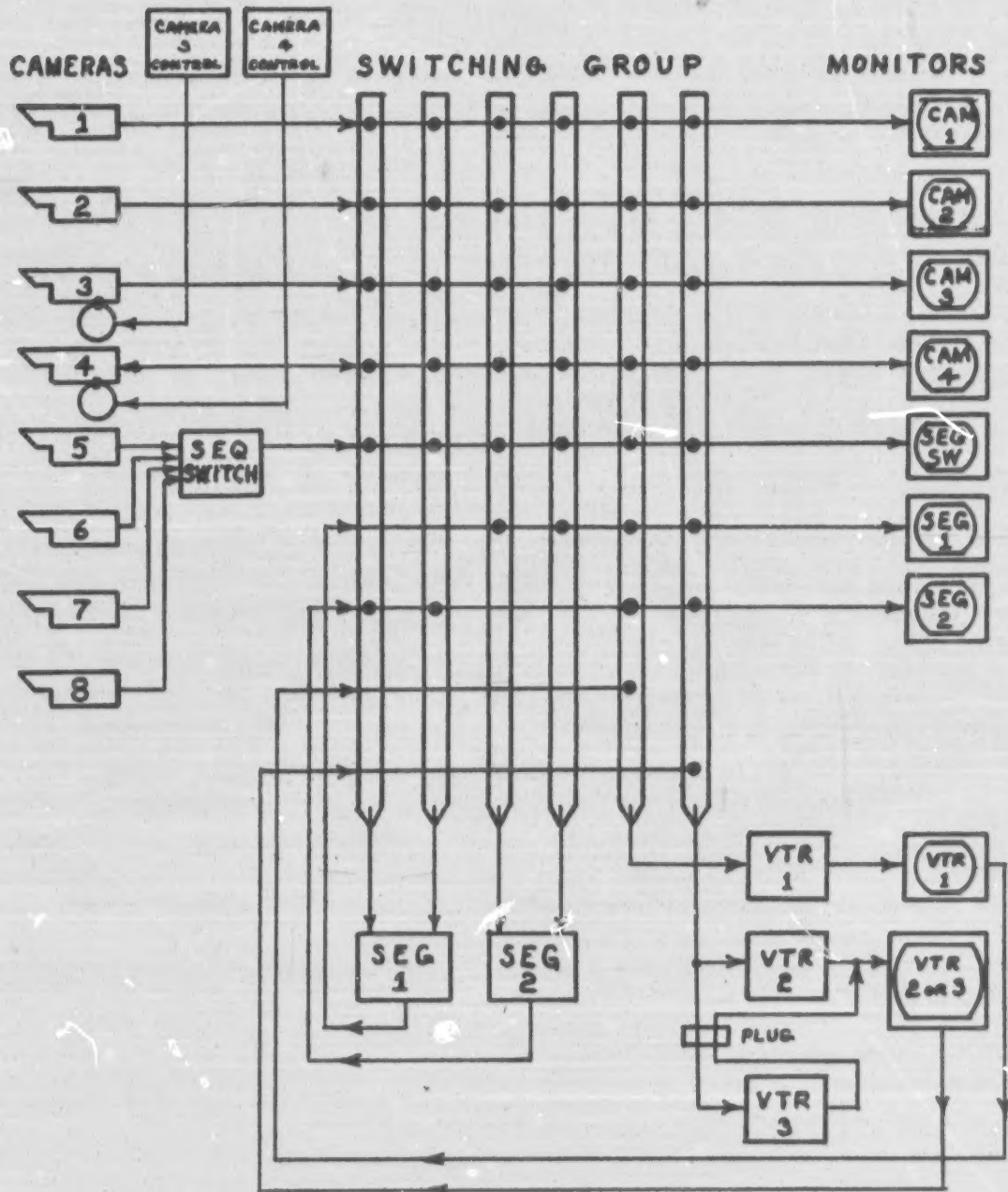


Figure 7 - Functional Switching and Control Diagram

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The output of VTR-1 is continuously displayed on the VTR-1 monitor, and can be connected as input (for tape editing) to VTR-2 or 3. Output of VTR-2 or VTR-3 (whichever is plugged into the system) is displayed on the VTR-2 monitor, and can be switched as input to VTR-1.

5.3.7 Video Tape Recorder - Time Lapse Three VTRs are furnished. Two of these are Javelin recorders with a time-lapse record capability. This means that the recorder can be operated at the normal recording/play back speed of 30 frames per second, or can record or playback at a lower speed - 7 frames per second - to achieve slow motion, speeded motion, or tape conservation objectives.

Thread Tape. To operate, it is necessary to first thread the recorder with video tape. A diagram in the box lid shows how the tape is threaded; further instructions are offered in the Operation and Maintenance Manual.

Turn on Power. Once inputs to be recorded have been selected and switched in, the recorder is activated by turning on power, starting the motor, and depressing the appropriate combination of keys (Figure 8). To turn power on (or off) press the POWER switch. This switch must be on to get a picture on the record monitor. To start (or stop) the motor and the rotary heads, press the MOTOR switch. This should be done only when ready to record or play, and the motor should be switched off each time recording or playback is stopped for more than a few seconds. In this recorder, anytime the motor is on, the recording heads rotate continuously against the tape and will cause significant wear on that portion of the tape.

Record. To record at normal speed - 30 frames or 7.5 inches per second - push the RECORD (red) button; then while holding that button down, press STANDARD PLAY. At this speed, a 7 inch reel records for approximately 1 hour.

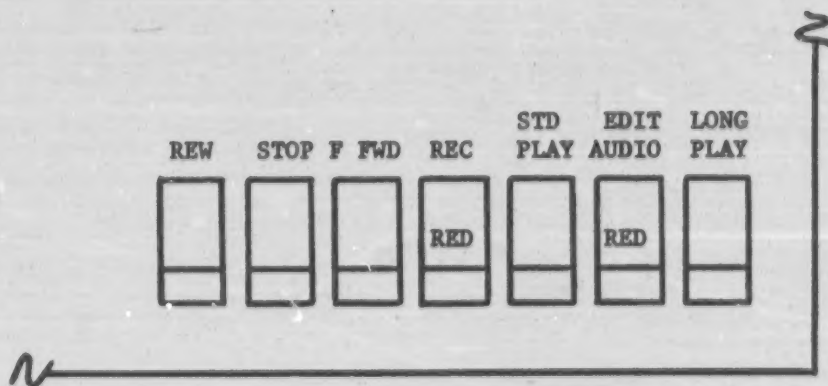
Play. To play back at normal speed, press only STANDARD PLAY.

Slow Motion. To play slow-motion, first record at normal speed. Then play back at slow speed: Press STANDARD PLAY, then LONG PLAY.

Slow Record. To record at slow speed press RECORD (red); while holding it down, press STANDARD PLAY then LONG PLAY. The recorder will now record at slow tape speed of 1/7th normal speed or 1 frame in each seven frames received from a camera.

Slow Play. To play back at slow speed, press STANDARD PLAY then LONG PLAY. The recorder will play back the action recorder (at Slow Record) without distortion of time, but with a motion which may

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TOP VIEW

Figure 8 - Control Layout - "Javelin" Time-Lapse Recorder

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appear jerky. Many tasks can be recorded in this manner without serious loss of detail, but at an approximate 85 percent economy in tape.

Speeded Motion. To play speeded motion, first record at slow speed, then play back at standard speed.

Stop Action. To play stop action, play back at slow speed; move the STILL lever to the left. This stops the tape. Turn the lever knob to the right, the picture can slowly be advanced from frame to frame.

Stop. To stop, press STOP.

Audio Edit. To edit the audio portion without affecting the video, press AUDIO EDIT (red), and hold it down while pressing STANDARD PLAY (and LONG PLAY if the original recording was slow record).

Rewind. To rewind or move tape forward without playing, press REWIND or FAST FORWARD, respectively.

In addition to operating these controls when recording, the instructor will have to keep track of the location on tape of each recorded sequence. As was noted before, this will require the maintenance of a recording log with readings of the index counters. Any time two recordings are being made, operation of the equipment will probably require the full attention of the instructor.

5.3.8 Video Tape Recorder - Remote Control One VTR is a Panasonic single-speed recorder. This unit includes a remote control assembly (COTO on Figure 1) which is connected to the VTR by a cable. The control unit can be moved to the point at which the operator is seated, and is both faster and easier to operate than are controls for the Javelin. In general, the Panasonic gives a high resolution of detail in playback.

Thread Tape. To use, thread the tape following instruction in the cover.

Turn on. Turn on the power and motor. The motor can be left running on this equipment, since when it is not recording or playing, the tape is automatically lifted off the rotary heads.

Operate. Press either the remote or regular function buttons, which correspond to controls of a conventional audio tape recorder.

Rewind Address. The Panasonic includes an automatic rewind address capability. When this device is engaged by setting a switch, the

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recording will automatically rewind to the zero position. Zero can be set at the beginning of the tape, or at any other tape position. Since the recorder is equipped with a remote control, an instructor at the console can simply press the rewind switch and continue another task while the recorder returns to the chosen (zero) setting. If, in recording or reviewing a tape, the operator observes an event which he will want to review, he resets the counter to zero at that point, and when he rewinds, the recording will stop at the same point. This capability is limited because it provides only a temporary index, only one address, and can be reached only by rewinding, not by forward searching.

5.3.9 Remote Control Cameras Cameras 3 and 4 are remotely controlled. Each control assembly consists of a motorized pan/tilt camera mounting assembly, a motorized lens control, and a control console panel on Bay 2 (Figure 9).

The motorized units mounted with the camera are designed for indoor use and can be used out of doors only while fully protected from the weather and extreme heat or cold. It is critically important to avoid pointing either cameras or lenses within 30 degrees of the sun.

Camera controls are located as shown in Figure 9. Each unit has four controls that may be adjusted each time the camera is moved. Camera angle (i.e., pan and tilt) is controlled by a single "joy-stick" type of control. This is easy to learn to operate. A complexity is introduced by lens adjustment. There are three separate lens adjustments possible -- zoom, light (iris), and focus. Facility in making these adjustments is not easily learned. The control for each function is a two-way switch and the combination of adjustments that are required for a given camera position does not follow a readily discernible pattern. Each setting may require a series of trial and error adjustments.

5.3.10 Audio Monitor and Record Six microphones are furnished, to pick up sound and speech for monitoring and recording. These microphones are input to the audio mixer, labeled "MIX" on Figure 1. Separate gain controls on the two mixer panels allow control of the volume input from each microphone. Output of the upper mixer is combined with that of the

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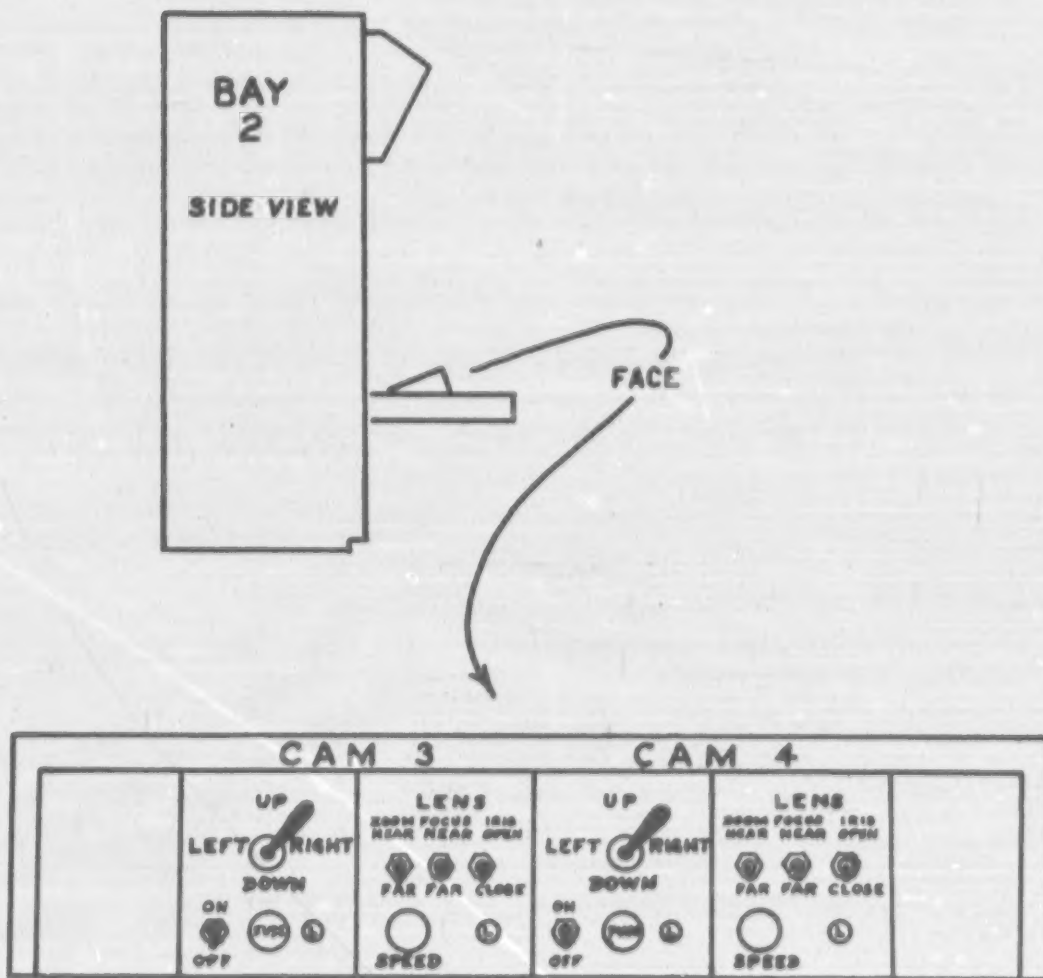


Figure 9 - Remote Camera Controls

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lower (master) mixer control. Overall recording or monitor signal level is adjusted by the master gain control on the lower mixer. Only one sound channel exists. It is connected to both recorders, and appears as audio any time either VTR is recording. Volume level meters on the mixers and recorders are used to recognize when sound levels are within the proper recording range.

5.3.11 Intercom System Intercommunication between the console and student stations can be provided by the intercom unit in Bay 1, labeled "COM" in Figure 1.

The master unit is shown in detail in Figure 10. By pushing any or all of the six selector buttons, the operator can select the stations he wants, and then must depress the lower button to talk. Students at the stations can break in to talk, any time the master station is silent. They must identify the station from which they are calling.

5.3.12 Lighting The video observation system is designed to operate, when possible, in ambient light. When that light is not adequate, or where the subject matter to be observed is in a shadow, and especially where fine detail is to be observed, artificial lighting may be needed. Two lighting sets of three lamps each are provided. The lights are provided with barn-door shields and diffusing screens to control glare. Glare and reflectance from bright surfaces can constitute a serious difficulty, since spots of glare can either block out picture quality or damage the cameras.

5.3.13 Lenses Lenses provided with the system consist of six 25 - 100 mm manual zoom lenses, two 15 - 150 mm motorized zoom lenses, one 9 mm wide angle lens, and two 2X extenders. In addition, each camera is equipped with a standard fixed lens.

The manual and remote control zoom lenses extend the capability of cameras significantly by permitting a greater range of camera positioning.

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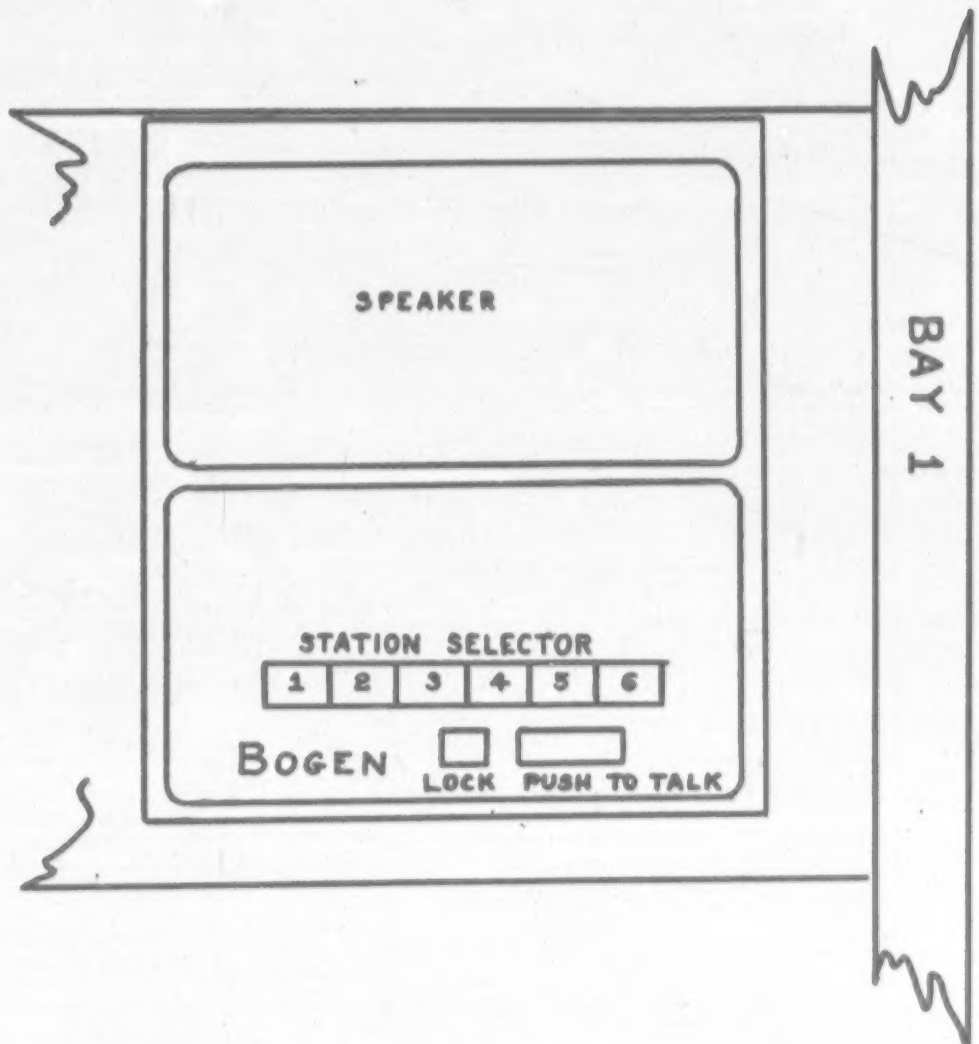


Figure 10 - Intercom Master Station

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If the standard lens is used, then the distance from the camera to the target is quite restricted. Using zoom lenses permits positioning the cameras in the most convenient or unobtrusive locations.

The 2X extenders double the range of the lenses when needed. Use of the extender reduces the field, or width of the picture, to the same extent that it increases the size of the image, and increases the light required on the target for good resolution.

The 9 mm lens is a wide-angle lens which permits capturing a broad field of view from relatively close distances. Its limitations are that it does not have great depth of field, and causes some distortion around the edge of the picture. It provides a complementary capability to the zoom lenses, in that it provides a great breadth of field, whereas the zoom lenses provide depth of field.

5.3.14 Mirrors Three mirrors and their mounting hardware provide line of sight access to areas that are otherwise inaccessible, or in which a camera would present an unacceptable intrusion.

In considering the use of mirrors, several concerns arise. First, a single mirror reverses the right-left orientation of the video display. This can be critical or not, depending upon the nature of the task. Second, using a mirror reduces the size of the image available to the camera, by increasing the relative distance to the image. This generally means that the mirror must be mounted in close proximity to the target.

The mirrors provided with the system are "front-surfaced", which means that the silvering is on the front rather than the back. This gives a truer image with less light loss. It means, however, that the mirror surface must not be touched, and must be protected from dirt or scratching.

5.3.15 Alternative Configurations The fully configured video observation system contains a variety of components, not all of which may be required by any one particular task. It is possible to assemble the system in reduced configurations, suited to the more limited requirements

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of particular tasks. It is possible to assemble the system (for instance) with only the number of cameras required by the task at hand, for monitoring only (without recorders), or without the audio or intercom capabilities.

Partial Console. Figure 2 illustrates the partial console which was actually applied during system field tests. This configuration is highly effective for applications in which one or two camera inputs are required (using cameras 3 and 4), and can feasibly use four camera inputs (cameras 1 through 4).

Cameras. Cameras 5 through 8, which are accessed through the SEQ, cannot be connected.

SEQ. No automatic sequential monitoring is possible.

Intercom. The intercom is not available.

Monitors. Cameras 1 and 2, if used, cannot be monitored directly, nor can the SEG displays. Those outputs can be seen only by switching them to a VTR and observing them on the VTR monitor.

Minimum Configurations. The minimum configuration possible is defined by Bay 2 with one camera, either camera 3 or 4, used only in monitor mode. Bay 2 must be employed because it contains the synchronization generator, and is the point of entrance for camera and power cables.

SECTION 6.0 SPECIFICATION OF METHOD

Earlier phases of this project identified an optimal configuration for a video system to support performance testing and student monitoring, and built such a system for use in the USAF. The next projected action was a field test to apply that system experimentally in three selected USAF technical training environments. Purposes of this field test were to verify the system mechanically and functionally, to acquire experience on which to base the writing of user instructions, to acquire sample recordings, and to test theories of application experimentally.

This section records the planning for the field tests, to the extent that it was pertinent to the experimental findings.

6.1 PRELIMINARY RATIONALE

It was initially intended that three general uses of the video system would be examined. These were:

- The training and standardization of test evaluation personnel.
- The conduct of real-time testing and instruction.
- The collection and evaluation of video performance samples.

For each of these uses, specific video techniques were to be applied and compared in the context of different training/testing environments. These are addressed in the subsequent sections of this report.

6.1.1 Training and Standardization of Test Rates The content validity of performance tests is generally recognized and accepted, since the relationship of each test task to job performance can be demonstrated by inspection. The reliability of such evaluations, however, is not so readily apparent when the judgement of human raters must be used. Such judgements are avoided to a large extent by using real outputs or products as measures of performance. Measures of performance such as restoration

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of a faulty item of equipment to operational condition leave little room for subjective judgement. Such criteria, however, are not always available, appropriate or sufficient. They may not provide an adequate normative basis for personnel actions, or they may provide insufficient training feedback information, or it may be impossible to apply the ultimate system criteria in the test environment. Thus, while system outputs are the most desirable performance criteria, it is not always possible to employ them. Instead, information may have to be collected on the "processes" the test subject uses. Doing so provides more grading points, more training feedback information, and more normative data for use in personnel selection.

But using process data may require subjective evaluations. Present methods available to control rater reliability include training raters on the evaluation criteria, using standard rating forms, spot-checking rater performance. What is missing in these techniques is a common, standardized stimulus field (performance) to which all raters can respond and which can serve as a baseline. The absence of such a standard prevents accurate assessment of the nature and amount of variability within any group of raters, and make effective remedial action to improve reliability difficult. One application of a video tape system is its use to overcome this difficulty.

To do this several things must be accomplished. First, a set of standardized performance tapes must be developed which depict criterion performances and quantified measurement points. Standard values have to be developed for the measures, and rater personnel must be trained in their application. Once this is done, the reliability of a rating program can be assessed by having personnel rate standard taped performances, and comparing their evaluations.

Standards are generally derived from the consensus of expert judgement, but the best source is the system itself. In other words, the operation which uses the outputs of the subject task can ideally

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determine the rate, the nature of the product, and the quality levels required for satisfactory performance. There are techniques for deriving such standards, but they are often not practical in training evaluation. That means that we are usually dependent on expert judgement.

In deriving task performance standards using expert personnel, it is important to focus on standards imposed by the system, as opposed to personal ones. A common tendency of content experts is to overrate the importance of minor performance elements. The test developer, by questioning and documenting the validity of the expert's standards, can increase the relevance of the standards imposed, without going to a full scale system analysis.

In performance testing, the most desirable form of criterion is one that subsumes all component performance requirements and represents, in one criterion performance, the correct and integrated performance of all sub-elements. When such a criterion is used the intricate scoring of sub-elements is accomplished automatically.

Sometimes the use of such a criterion is not feasible. For example, the ultimate criterion for successful performance of a lubrication task might be that the components in question do not fail due to improper lubrication over the succeeding 100 hours of use. There are obvious restrictions against employing such a criterion -- time, safety, and cost, to mention a few. When such situations are encountered, it is necessary to substitute evaluations of the process by which the criterion is accomplished and to define sub-products which result from that process, and which can be evaluated and summed to give a proximate measure of criterion achievement.

When this is necessary it is very easy to begin introducing subjective judgements about the process, judgements which may or may not be valid. These must be evaluated to ensure that the role of such judgements is minimized and that each is in fact relevant. In the

lubrication process, for example, the subject may have to be evaluated on the smoothness of the layer of grease that has been applied. Likewise in soldering, the appearance (dull, shiny, etc.) of the solder may be pointed out by experts as a proper clue to the adequacy of the solder joint. Without judging the relevance of these particular measures, it is this type of measure that should be carefully examined. Once such subjective judgements are introduced, the reliability of the overall evaluations will be reduced.

As an alternative to judgements which subsume sub-elements of the task, it is sometimes possible to identify sub-products in the task which can be separately evaluated to give a composite evaluation. For example, the soldering task can be broken into sub-elements to generate objective measurement points. These elements include component identification, component removal, replacement installation, determination of polarity, choice of solder, choice of soldering iron size, use of heat sinks, and economy of solder used. Each of these sub-elements can now be assigned an independent quantitative value against which to be evaluated. Some elements may be critical; they would be assigned a straight right/wrong dichotomy. Part selection (for example) may be such an item. A man either selects the right component or the wrong one. If it is wrong it may be sufficiently critical to fail him on the total task. Regardless of how well a man does everything else, if he installs the wrong component there is no way for the criterion task to be successful. Such a decision would be dependent upon the purpose of the test. For remedial purposes, it is useful to know which element has failed, so that accurate corrective steps can be taken; for other purposes it may be more important to know whether the full criterion performance can be satisfactorily performed.

The first step in quantifying job task performance for evaluation is to identify the elements that make up the task. By so doing a

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basis is established for moving away from a judgemental evaluation which cannot be analyzed for comparative purposes, and toward an evaluation which will provide quantitative benchmarks.

The validity of a job sample evaluation is dependent on correlation of that evaluation with performance which meets job specifications. This validity can be traced out to the user of the product and ultimately to the readiness of the unit which incorporates the product into its operation. Such a tracing procedure is difficult, costly and time consuming to execute. More often a proximate criterion must be used to short cut this lengthy process. The short cut is represented by the judgement of some individual, often a supervisor or instructor, who presumably knows the specification of the product which make it support the operation properly.

The problem in using this proximate criterion in preference to the more distal one is that people, even supervisors, seldom agree. There are many reasons for this disagreement; biases of one type or another, failure to observe carefully, lack of knowledge, or a number of other factors. Still for practical purposes judgement by experts is the feasible point at which to start. If procedures can be developed to reduce differences of opinion, and to resolve the reasons for disparity of judgement, then a useful method for making reliable and valid measurements of performance can be attained.

Let us examine how this process might be accomplished:

The starting point is a performance recorded on video tape. Several experts are asked to rate this performance.

The raters are then asked to be explicit about the basis of their judgement.

The reasons one rater gives are compared to others, either in private discussions or in a group. Some resolution of differences of opinion is expected from this process.

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To the extent that differences of opinion appear, the experimenters analyze the consequences upon an actual operation, of the performance being judged. This process of analysis will presumably resolve most remaining differences of opinion.

The result is a methodology for evaluating job sample performance on video tape. To be complete for any task it must prescribe how the camera will be placed and what data are to be observed by observers. The procedure can be incorporated in a check list.

The next step is to make new tapes, have them rated by the same experts, and then introduce new expert raters and have them make ratings using the check list. To the extent that ratings obtained in this way are reliable, their validity can be reasonably assumed.

Jet Mechanic Testing Application The rationale just outlined could presumably be applied in each of the three projected test environments, the first of which was jet mechanic training. Here the point of departure for task quantification was presumed to be defined test tasks for Block V of the jet mechanics course. While these tasks had not been subjected to a formal validation as to their job criterion orientation, they contained sufficient face and content validity to suggest their appropriateness for this project. The types of tasks that were represented in the subject tests fell into five general categories:

Mechanical Assembly

Inspection

Checkout

Servicing

Administration

The mechanical assembly category included component removal and replacement and electrical/mechanical adjustment. In this task

electrical/mechanical connections were made and unmade, parts replaced, and adjustments made in accordance with published or other standards.

Inspection included tasks that required detecting flaws or other conditions requiring remedial action. It denoted an unordered, but not random activity, structured but not sequence-dependent.

Checkout activities were those which consisted of a systematic checking of a system or sub-system, submitting it to a defined, sequence-oriented procedure. For example, the check out of a lighting system required following a check list of switch operations.

Servicing tasks included POL servicing, and such preventive maintenance functions as cleaning, tightening, or otherwise maintaining equipment in good working order.

Administrative tasks included the filling out of forms, reports, and records associated with maintenance tasks. Such tasks, of course, resulted in a written record which could be processed (graded, etc.) in a conventional manner.

Each of these main categories of tasks presented sets of characteristics that could be analyzed in terms of task quantification possibilities. A mechanical assembly task might be broken down as shown in Table 5.

Such a breakdown identifies scoring elements for any given test task. The next thing is to review these elements with experts to insure that they are complete and accurate, and then to assign values to them for evaluation purposes. Meaningful is defined as a grading scheme that can be applied objectively, and that weighs the elements in their relative criticality to task performance. For the first action shown in Table 5, "unbutton aircraft section", proper tool usage must be defined and its limits established. If a screwdriver is the proper tool, is the size of the screwdriver critical? A required precaution is to avoid using scoring criteria simply because they are convenient and available. If the size of screwdriver

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TABLE 5. TASK BREAKDOWN -- MECHANICAL ASSEMBLY TASK

Flight Control Removal and Replacement

Action	Scoring Criteria
Unbutton aircraft section	- Proper tool usage - Proper panel removal
Locate specified component	- Proper location and identification
Remove blocking components to gain access to target component	- Proper blocking components removed, no excess - Proper tool usage - Proper technique
Remove target component	- Proper tool usage - Proper sequence
Rig, adjust, or otherwise prepare replacement component	- Proper replacement selected - Proper adjustment/preparation
Install new component	- Proper sequence - Proper tools - Proper direction - Proper safety wiring
Reassemble blocking parts	- Proper sequence - Proper tools - Proper direction - Proper safety wiring
Button aircraft section	- Proper tools - Proper installation

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used is a point of little overall impact on performance, it should be ignored. But if the subject uses vice-grip pliers where a socket wrench is required, such an error might be of significant consequence. Through careful analysis, then, objective measures can be identified that discriminate on critical parameters between acceptable and unacceptable performance. This type of analysis must be conducted jointly by a behavioral analyst and content experts; in this project, analysts were to use a new analytical tool - video tapes of actual performance which would serve as a constant, repeatable stimulus field for their common focus.

Power Lineman Pretesting Application The possibility of developing quantifiable test evaluation materials was also to be examined in the power lineman pretesting application. Task elements to be examined in this area were those included in pole climbing agility used as a predictor of student success in training. The decision of an evaluator to accept or reject a candidate for training was made on the basis of his judgement of the candidate's coordination, strength, confidence, and lack of or control of fear of heights as exemplified in his climbing two poles. At this point the student had had no climbing instruction and, in fact, had not yet been accepted for training. Performance deficiencies that might be overcome through training and practice were to be ignored by the evaluator at this point. The elements of task performance, then, that could be captured on video tape for analysis were:

Speed

Coordination (smoothness of climb)

Placement of hands and feet

Facial expression

Strength

Focus of the climbers attention (i.e., upward, downward, foot placement)

Height reached.

Following the general approach previously outlined, tapes of a number of subjects could be made. Evaluators could then review the tapes to determine which of the suggested parameters were measurable from the tapes. Rating scales appropriate to each would be established and verified with the evaluators. At this point other evaluators would be brought in to apply the developed standards to tapes of student performance and to determine the reliability of the evaluation standards developed.

The pole climbing activity presented an evaluation task quite different from that of the aircraft repair. The latter had a number of objective measurement points available, whereas the pole climbing evaluation required a series of subjective judgements about an individual's performance of a single task.

Instructor Training Application The third application area to be studied was instructor training. The evaluation parameters available here were more numerous than in the power lineman evaluation, but just as subjective. The specific task to be studied was that of a student instructor conducting a class, before a real audience of actual students.

Evaluation parameters for this task were already well developed, since such evaluations had been conducted in person by raters for some time. Instructor training is an activity common to all schools and training centers, so a lot of thought and effort had been given to these evaluations. This resulted in the development of a standardized evaluation form which was currently being considered for adoption by all Air Force instructor training activities. This form defined a considerable number of evaluation parameters; to be determined was which of these would "come through" on video tape, and which would not. In addition new capabilities would be available, such as simultaneous split-screen viewing of class and instructor.

An additional consideration was that of sampling. One problem was the time required for an evaluator to sit through a complete class presentation. If he had to sit through an equally long video tape presentation, all that would be gained is some scheduling flexibility; the evaluator could watch it at his convenience; he could replay any portion desired; and he had a useful tool for critiquing the student instructor (which is why video is usually used in instructor training). If valid evaluations could be made by sampling limited segments of an instructor presentation, as contrasted with viewing the whole presentation, then significant advantages might be realized.

For those purposes it was proposed to identify, at a gross level, whether sufficient information could be captured and interpreted, using the designed video system, to warrant further investigation. This would be done by again following the general approach of taping materials, having experts identify the criterion points and standards, and then having other evaluators attempt to apply the standards to taped presentations.

6.1.2 Conducting Real Time Testing and Instruction Another capability of the video system was using it to observe and interact with students operating in dispersed locations. The best application in which to examine this potential was jet mechanic testing. In this application there was a reason for students to question the instructor, and to receive verbal guidance and instruction. A major parameter to be examined in this application was the demand imposed on the instructor's span of control by system operation. It was hypothesized that a video system could expand the instructor's effectiveness, since under existing conditions he was required to move from one testing location to another, on a random demand basis, as students required evaluation or assistance. Having a centralized video network might permit him to observe and communicate with the students without moving from one location to another. To be examined was whether the system did in fact permit

this flexibility, or whether the demands of operating the system offset the potential gains. Specific questions to be examined were:

Can sufficient visual access to student performance be provided by video cameras?

How many simultaneous displays can a single instructor monitor effectively?

Can the system provide adequate resolution for discrimination of student performance?

Can a method of sequential sampling of student activities be effectively monitored by an instructor?

Does instructor control over camera position (i.e., remote control) provide a net gain in effectiveness when the added operational work load is considered?

What gains in visual access are realized when multiple views of an operation are provided? On multiple monitors? On the same monitor?

What is utility of inter-communication capability and what is the operator load associated with its use?

6.1.3 Collecting and Evaluating Video Tape Recordings of Performance The alternative means of assessing student performance using the video system is to record performances and score them later, rather than in real time. This mode of operation was to be utilized experimentally in all three applications. In the jet mechanic area, the need to record was expected to arise as attention channels become filled, and the instructor has to fall back on recording as a delayed means of observation. In both the pole climbing and instructor training applications, however, the recorded mode was to be the primary rather than alternative method of use. The specific questions that were to be addressed in the recorded mode evaluation are:

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How effectively can an instructor operate a system that has the recording capability added to the live observation capability?

What is the relative effectiveness of alternative methods for keeping track of the location of recorded sequences for later access?

What is the relative effectiveness of different methods of reviewing taped material?

Does the recorded image provide sufficient resolution for evaluation purposes? Under what conditions does degradation occur?

What configurations of recorded operations are most functional or necessary?

6.2 FINAL RESEARCH OBJECTIVES

By the time of the field application tests (May, 1973), plans for the test had been further refined, and research objectives were reduced to a series of specific questions. Video techniques were to be applied experimentally in three selected training areas, and with the general objectives of:

Evaluating the utility of the video system in improving test administrator reliability, performance testing, and performance monitor.

Evaluating video technical capabilities of the system, and developing basic video monitoring techniques.

Evaluating the video system mechanically and electronically.

Gathering data for user manuals, and gathering tape recorded video samples of student performance.

System tests were conducted in three training environments; jet aircraft mechanic performance testing, power lineman pretesting, and technical instructor training.

The specific questions investigated by these tests are detailed in Appendix A, and included the principle questions listed following.

6.2.1 Utility of Video as a Tool in Monitoring and Measurement of Performance.

Product and Process Content What product (observable physical end product) criteria are critical to evaluation of each task? What process (activity) criteria? To what extent can those criteria be fully monitored through, or recorded by, the video system? What is gained or lost by using the system, as compared to direct observation or conventional measurement techniques?

Student/Evaluator Feedback What effect does use of the video system have on the speed, effectiveness and frequency of remediation?

Time What gain or loss of time results from using video?

Operator Load What loads are imposed by subsystems of the video system on the time, attention, and physical capabilities of the instructor? What are the costs and benefits of using those sub-systems, as compared to conventional observations? What loads are imposed by:

Monitors?

Sequential switch?

Special effects generator?

Remote pan/tilt?

Remote zoom?

Remote focus and iris?

Audio monitor-record?

Intercom?

Record/replay?

Tape threading and handling?

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Changing recorders?

Switching?

6.2.2 Videotechnical Capabilities

Video Feasibility Is it technically feasible to monitor or record critical (criterion) elements of specific tasks using the video system? Is camera access possible? How many cameras are required to monitor all significant product features of any task? To monitor task performance? What limitations are imposed by lighting? By video resolution of the system?

Supporting Audio Are supporting audio systems useful or required for any particular task? Audio monitor or record? Intercom?

Subsystem Capabilities What are the uses and limitations in relation to any specific task of:

The sequential switch?

The special effects generator?

The remote zoom control?

The remote focus and iris control?

The remote focus and iris controls?

The mirrors?

Recording and Replay Is it technically feasible to record and replay critical features of tasks or task performance? What are the capabilities or limitations of the remote and mechanically controlled recorders? Of slowed, speeded and stop-frame capabilities? What problems occur in logging and relocating recorded information?

6.2.3 Mechanical and Electronic Characteristics

Durability How durable is the system? What features or limitations in durability of the system or components were noted as a result of shipment, reassembly, and movement to successive test areas?

Suitability How well suited is the physical configuration to its intended applications? How difficult is it to assemble and use? How well is it fitted to the human user? What physical or electronic features of the system might be improved in any future redesign?

6.3 SELECTION OF TASKS

Three general areas of technical training had been selected earlier as likely to provide optimum conditions for field testing of the video system and as meeting the experimental objectives outlined in Section 6.2 These areas were:

Phase tests, performed on a trainer aircraft, by jet aircraft mechanic trainees.

Pole climbing pretests, administered to airmen who were candidates for power linemen training.

Live classroom training of technical instructors.

All selected areas were at Sheppard AFB, Texas. Some changes in circumstances occurred between the time those task areas were chosen and the time of the field tests. Most significantly, reduction in student loads resulted in changes in scheduling which limited the opportunity of URS/Matrix personnel to observe and monitor pole climbing and technical instructor performances.

6.3.1 Jet Aircraft Mechanic Area - Selection of Tasks On arrival at the test site, URS/Matrix personnel reviewed current student testing procedures used on the F-100 Aircraft Maintenance Trainer (and associated training mockups), to select subtasks for video study. Thirteen (13) subtasks were selected initially, on the basis of their potential to:

Explore video techniques and to define limitations of the video system.

Exercise different configurations and sub-systems.

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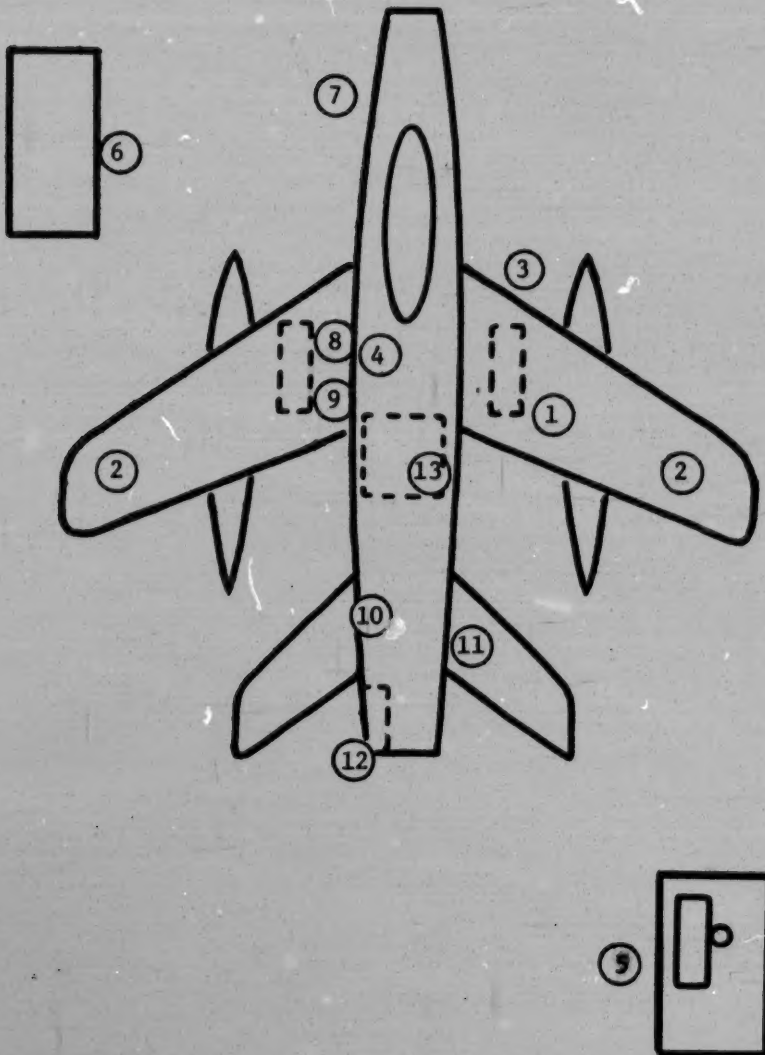


Figure 11 - Location of Tasks Examined

Identify applications in training and testing.

Subtasks initially selected are listed in Table 6, and their physical locations are shown on Figure 11. On two subsequent days, trainees were observed performing the listed subtasks in testing sessions, and at that time 7 tasks were eliminated from further study (observations follow below). Task numbers are those used in Table 6, on Figure 11, and on subsequent figures.

Task 1 - Aileron Bungee This task, under the right wing, was selected for further study and is treated in detail by Section 7.1.

Task 2 - wing Mooring Actually two very similar tasks, one under each wing, are described by the same test item and T.O. reference. This task was selected for further study and is treated in detail in Section 7.2.

Task 3 - Chock Wheels

Task Description: This task required wooden chocks to be placed on each side of one gear wheel, and ties to be inserted in the chocks before mooring the wing.

Test Criteria: The critical point was completion of a four step task - two chocks and two ties.

Observations: The task lent itself readily to observation through a central video monitor. The chocks were yellow, easy to discriminate on monochrome video, and the product criteria were gross details which showed well on the monitors, even in the poor lighting under the right wing. Nevertheless the task was eliminated from further study because:

Students performed it readily with no observed failures, and it was experimentally uninteresting.

Video technical problems were minimal, and not experimentally interesting.

Positioning tripod cameras in the area would have impeded

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TABLE 6. SUBTASKS EXAMINED -- F-100 MAINTENANCE AREA

Location	Task/T.O. Reference
1	<u>Aileron Bungee</u> - Remove and replace right aileron artificial feel bungee. T.O. IF-100 D (I)-2-5, Page 5-32, Fig 5-1.
2	<u>Wing Mooring</u> - Moor right wing with bowline knot. T.O. IF-100 D (I)-2-5, Page 5-12, Fig 5-6.
3	<u>Chock Wheels</u> - Properly chock (R or L) main wheels for mooring. T.O. IF-100 C (I)-2-1, Page 5-10, Fig 5-5, step 3.
4	<u>Gear Door</u> - Inspect landing gear door locks. T.O. No reference.
5	<u>Wheel and Brake</u> - Remove and replace wheel and brake assembly. T.O. IF-102A-2-8, Page 1-23, & 8-9, Fig 1-11 and 8-3.
6	<u>Wheel Bearing</u> - Remove, clean, inspect, lubricate and replace wheel bearing. T.O. IF-100 C (I)-2-1, Page 10-9, Fig 10-5.
7	<u>Lighting</u> - Aircraft lighting check. T.O. IF-100 C (I)-2-6, Pages 4-13 & 4-14.
8	<u>Gear Pins</u> - Install gear safety pins for towing. T.O. IF-100 C (I)-2-1, Pages 5-10, Fig 5-5, step 1 and Fig 1-7, sheet 1 & 2.
9	<u>Door Linkage</u> - Remove and replace left shock strut fairing door linkage. T.O. IF-100 C (I)-2-4, Pages 3-115 & 3-116, Fig 3-37.
10	<u>Rudder Bungee</u> - Remove and replace rudder artificial bungee. T.O. IF-100 D (I)-2-5, Page 6-25, Fig 6-10.
11	<u>Stabilizer Bolts</u> - Safety wire stabilizer mounting bolts and nuts. T.O. IF-100 D (I)-2-5, Pages 4-44, Fig 4-8.
12	<u>Chute Release</u> - Inspect and operational check of drag chute release system. T.O. IF-100 C (I)-2-2, Page 12-4, Fig 12-7.
13	<u>Fuel Filter</u> - Remove and replace engine fuel filter. T.O. IF-100 C (I)-2-2, Page 2-113, Fig 2-1.

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student movement, and obstructed video access to the more interesting tasks 1 and 9. This would not be a problem in a permanent installation, since cameras could be mounted in or under the wings.

Task 4 - Gear Door

Task Description: This was a visual inspection for wear or damage to door locks, which were located at each side of the aircraft in doors which opened downward from the belly of the aircraft, back to back, from hinges near the center line. The open door panels hung downward from the center line, and were inspected from the area under each wing.

Test Criteria: Criteria for this task were not listed in the T.O.; instructor statements concerning criteria were conflicting.

Observations: The task was eliminated from further study because:

Video observation would be limited to simply observing that a student looks at the door locks.

The criteria for correct performance was recognition and reporting of mechanical defects which were already known to the evaluators. There was no role for video in monitoring such performance.

Goals were uncertain, and documentation lacking.

Task 5 - Wheel and Brake A wheel and brake assembly was mounted separately, as a training mockup, to the right rear of the aircraft (Figure 11). This task was selected for further study, and is treated in detail by Section 7.3.

Task 6 - Wheel Bearing

Task Description: This task was performed at a bench trainer to the left of the training aircraft. The trainee removed a bearing, cleaned it using solvent, and repacked it with grease.

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Test Criteria: Critical points were cleaning, recognition of inspection criteria, and repacking in such a manner as to assure that spaces within the roller raceway were filled with grease. This discrimination depended on observing hand movements during packing, and observing extrusion of excess grease around the rollers and raceway. During the time of the study this test was conducted dry, since no solvent or grease was available.

Observations: This task was of high interest because a process measure - how the hand and lubricants move in packing the bearing - was critical. The test was eliminated from further study, however, since it was being simulated without lubricants.

Task 7 - Lighting

Task Description: This task was performed by observing whether aircraft lights did in fact function when the proper switches in the cockpit were on.

Test Criteria: The training aircraft had been set up with selected circuits not functioning; the critical measure was the trainee's successful identification of those circuits.

Observations: As conducted this was a nearly perfect product-criterion controlled test. Paper and pencil responses identified defective lights; video was not likely to assist scoring of this task, and it was eliminated from further study.

Task 8 - Gear Pins

Task Description: This task required installation of locking pins in the gear before attaching the towbar to the nose wheel.

Test Criterion: Pins were in place.

Observations: This task was eliminated from further study for the same reasons as the wheel chock task (Task 3).

Task 9 - Door Linkage This task, located under the left wing, was selected for study and is treated in detail by Section 7.4.

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Task 10 - Rudder Bungee This task was located on the left face of the vertical stabilizer. It was selected for further study, but observations were limited by the fact that no student performed the task during the time of the URS/Matrix field test. Video techniques are treated by Section 7.5.

Task 11 - Stabilizer Bolts This task was located at the root of the right horizontal stabilizer. It was scheduled for further study, but like 10 above was not assigned as a student task during the time of URS/Matrix field test. Video techniques are described in Section 7.6.

Task 12 - Chute Release This task was located at the lower left of the tail assembly, and was performed from the ground at the rear of the aircraft. It was included in recordings made 22 May for its videotechnical interest only. Video techniques are described in Section 7.7

Task 13 - Fuel Filter This task was located within the fuselage of the aircraft. It was selected for further study and is treated in detail by Section 7.8.

Miscellaneous Task - Tripod Jack Not initially identified, but used later in monitoring experiments, was a task performed using a tripod jack. See Figure 3 - paragraph 7.9.

6.3.2 Power Linemen Area - Pole Climbing Pretest This task was selected for observation because of high interest expressed by the resident instructor staff of the power linemen course, and because the task concerned offered unique technical opportunities.

Description of the Task A principle cause of student eliminations in the power linemen course has been real or claimed fear of height, and inability to acquire the coordinations needed to work while mounted on a pole. Therefore the school has developed pre-testing procedures designed to screen out those candidates who lack

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coordination or who exhibit fear of high places. The pretest included a written questionnaire plus a practical climbing test in which candidates, without prior familiarization, are required to climb one pole using climbing spikes, and one pole using step-cleats mounted to the pole.

Criteria The criterion for selection was the judgement of experienced instructors, as to whether the candidate exhibited coordination, confidence, and ability to overcome fear of high places.

Experimental Outcomes It was hoped that this experimental application would:

Provide technical evaluation of the video system in outdoor use.

Assist in evaluating potential of the video system for the standardization of rating techniques.

Provide video documentation by which school personnel could review their judgements regarding students who later presented themselves for voluntary elimination, claiming fear of heights.

6.3.3 Instructor Evaluation Application This task was selected for the field test because of the high presumed value of video in instructor training. It was assumed that a capability to record the student instructor's performance, simultaneously with reactions of his class, could be useful to the instructor in scoring that performance at a time of greatest convenience.

Description of the Task A newly trained technical instructor was assigned practical training, instructing a real class in an applied setting. Classroom activity consisted of an initial lecture/demonstration, during which students sat as in a standard classroom, followed by a laboratory phase during which the students worked in training booths which surrounded two sides of the classroom. The task concerned was an electric power fault isolation exercise.

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Criteria Criteria for the instructor task were complex, requiring applied demonstration of principles of instruction presumably learned earlier, and successful interaction with students in class.

Experimental Outcomes It was hoped that this experimental application would:

Assist in defining the value of recorded video as a tool by which student instructors could review their own performance, and observe the effects of that performance on a class.

Assist in defining the value of video recording for use in post-exercise evaluations.

Provide for evaluation of the audio-record capability.

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SECTION 7.0 JET AIRCRAFT VIDEO TESTS

URS/Matrix personnel received the Video Observation System from the builder, shipped it to Sheppard AFB, and assembled it initially in its full configuration (Figure 1) in the jet aircraft maintenance testing area. The system was operational in about 48 hours, having required 16 man-hours to assemble. Of this time approximately 12 man-hours were required for physical handling and unpacking, and 4 man-hours for plug-in, testing and adjustment. All subsystems were found to be fully operational following shipment.

The equipment performed well. After some experiment, satisfactory video monitoring was achieved for all selected tasks. The equipment performed with consistent reliability, in spite of limited access to power. A serious difficulty was the interference of glare and high-lights, caused by the highly reflective aircraft surfaces. Figure 12 shows the camera layouts used on 16, 17 and 18 May. Figure 13 shows camera layouts used on 21 and 22 May. Figures 14 and 15 show the lighting levels which existed in the training area, and which determined video techniques. Figure 16 (page 148) is a cutaway view of the aircraft showing the camera, light and mirror used 16 - 21 May to study task 13.

Following check-out, URS/Matrix personnel began exploratory use of the video system to monitor and record trainee performance in selected jet aircraft mechanic tasks. The target activity was a series of job performance tests, being administered at the conclusion of a block of instruction in flight-line airframe maintenance and service.

A major preliminary objective was to verify that video observation could be useful, considering the already well developed scoring system in use at this point, and the nature of the tests in progress. These block tests were highly developed, job-criterion referenced tests, which were performed on an F-100 trainer and associated mock-ups under

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Figure 12 - Tasks Selected for Study and Location of Cameras

16-17 May 1973

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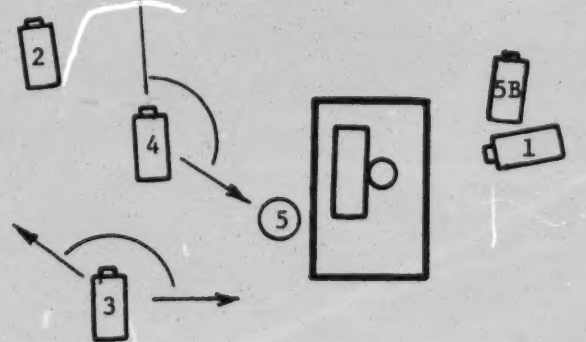
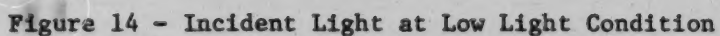


Figure 13 - Camera Layout and Lighting

22 May 1973

F-100 AIRCRAFT MAINTENANCE TRAINER



0900 Hours 22 May 1973

F-100 AIRCRAFT MAINTENANCE TRAINER

Figure 14 - Continued: NOTES

- (A) Less than 5 FC.
- (B) Less than 2 FC by ambient light. 300 FC at task when using video system lighting shown at Figure 13.
- (C) Less than 5 FC by ambient light. 300-500 FC at task when using video system lighting as shown at Figure 13.
- (D) Interior of fuselage. No measurable light. 500 FC at task when lighted.
- (E) Less than 5 FC.
- (F) From 10 FC at floor level to 35 FC at 5 feet up.
- (G) From 10 FC at floor level to 25 FC at 5 feet up.
- (H) Overhead incandescent light at this point, 20 feet from floor, is source of ambient lighting.

CONDITIONS: 0900 hours 22 May 1973. Sky overcast, 50% of light from overhead incandescent hangar lighting. Skylight comes from hangar doors to the right, closed.

NOTATION: All figures represent foot-candles (FC) light incident at surface.

Figure 14 (Continued)

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F-100 AIRCRAFT MAINTENANCE TRAINER

LEGEND

- (20) FC incident at horizontal or oblique upper surface
- (20) → FC at vertical surface
- (20) ← FC at under surface
- (A) (Letter) See note on page following

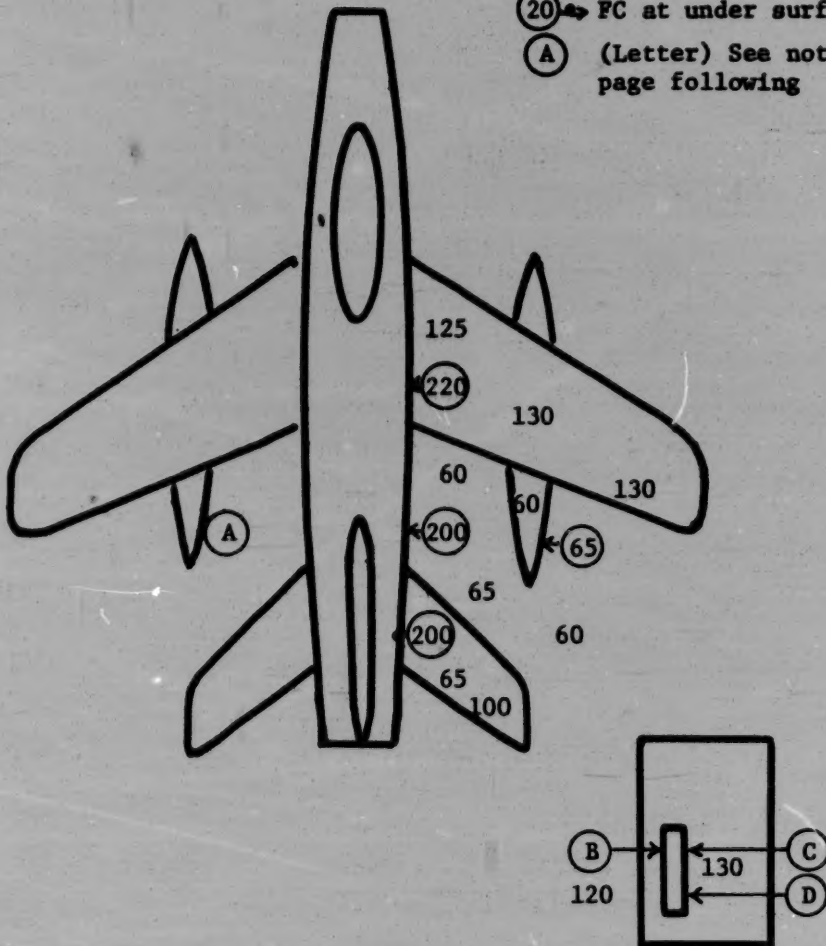


Figure 15 - Incident Light at High Light Condition

1100 Hours 22 May 1973

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F-100 AIRCRAFT MAINTENANCE TRAINER

Figure 15 - Continued: NOTES

- (A) All lighting to left and under aircraft is same as in figure 14 (low light condition)
- (B) Less than 5 FC
- (C) Ranging from 100 FC at floor to 250 FC at 5 feet
- (D) Ranging from 100 FC at floor to 150 FC at 5 feet

CONDITIONS: 1100 hours 22 May 1973. Sky clear, hangar doors (to right) partly open. Less than 10% of illumination from overhead incandescent lighting.

NOTATION: All figure represent foot-candles (FC) light incident at the surface.

Figure 15 (Continued)

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realistic field conditions. Each test item consisted of a written task instruction which directed an operation or inspection to be performed, and which then was scored objectively on the basis of either:

Product criteria in the form of a recognizable hardware end condition (landing gear locking pins are fully inserted),

or:

Product criteria in the form of a student's correct observation and report of a recognizable hardware condition (left wing clearance light does not function).

These tests were nearly ideal objective, criterion referenced measures; therefore the process by which end-product criteria were achieved did not (in theory) enter into the scoring system. Presumably, if a working mechanic could use the Technical Order to complete his tasks in the available time, no one cared how he did so. If therefore, as presumed, the tests concerned only end-products and not the processes by which they were achieved, then the activity of the trainees had relatively small importance, and since the virtue of video is to capture action, the value of video was in question. The URS/Matrix study was therefore looking particularly for:

Points at which process criteria were unconsciously being applied.

Points at which product criteria did not fully define competent performance.

Points at which video offered economy of time or effort, as compared to direct observation.

Points at which safety required active monitoring of performance.

Points at which the use of product measures might endanger learning objectives.

7.1 TASK 1 - AILERON BUNGEE

7.1.1 Task Description Access to this bungee was from beneath the right wing, just aft of the landing gear, and between the gear strut and the wing tank. A panel on the lower wing surface was left off permanently (on the trainer) for student access. The bungee is an

elongated cylinder into which a metal shaft slides from one end; at each end is a collar (one on the outer end of the cylinder and one on the shaft) by which the bungee is attached to the aileron control system. Visual inspection of the installed bungee was partly impeded by wing structures and hydraulic lines.

7.1.2 Test Criteria Critical criteria for verification of performance included:

That the bungee was installed with the cylinder end to the inboard side.

That bolts and nuts were inserted from the correct direction.

7.1.3 Observations Task 1 was a case in which the instructor had to expend time to personally walk around the aircraft and to verify installation of the bungee in an area difficult to view; video offered the possibility of saving some of that time and effort. The task raised technical questions as to whether trainee body movements could block video access, whether critical small parts could be seen through a video system, whether all pertinent action and criterion product points could be contained within a video frame, whether sufficient visual contrast existed to make the subject matter visible, whether audio communication was necessary for task evaluation, and questions regarding which features of the video system were useful in monitoring or recording the task. These, and other experimental questions concerning application of video techniques to the subtask, are further detailed in Appendix A.

7.1.4 Video Technique, 17-18 May Initial attempts to monitor repair of the aileron bungee employed a camera positioned inboard of the aft end of the right wing tank, looking forward and up to the under-surface of the wing. The poor light at the task and contrasting highlighting of background objects forward of the aircraft made it impossible to achieve an image at the monitor (See Figure 15, Lighting).

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Lights were brought onto the task area and tried from several angles. In every case, high glare from tank, wing and gear surfaces blocked out the monitor image and threatened to damage the vidicon tube. Cameras placed aft of the tank proved to be in the way of the student performing the task. When they were placed far enough to the rear to be out of the way, the bungee was not visible.

Finally, camera 6 was placed on a lowboy mounting under the edge of the fuselage to the left rear of the tank (6A, Figure 12). Lights at the aft end of the tank between landing gear and wheel gave excellent resolution of the bungee, although trainee performance was frequently obscured by body and hand movements. Criterion points of bungee attachment were clearly visible.

Camera 4 (remotely controlled) was positioned so that it could pan to the underwing area, permitting observation of both the bungee (through camera 6) and of the student installing it (through camera 4). Highlights around the wheel assembly and glare from the tank were controlled using barndoors and difusing screens on the lights.

The lowboy mounting proved to be hazardous. The weight of the camera, which is mounted between two of the tripod legs, placed the center of gravity precariously forward. When the leg opposite the camera was shortened, the tripod was less likely to be knocked or pulled over, but still needed to be protected.

Special Effects Generator (SEG) displays were constructed and an optimum configuration achieved in which the bungee (camera 6 output) was seen laterally across the monitor screen with the underwing area (camera 4 output) shown on a quarter-screen. The full screen showed details of the bungee and of tool movements during installation, while the quarter screen gave a general view of the student's actions.

The general view (camera 4) gave no criterion information. It did:

Make it easier to interpret movements which otherwise were seen as disconnected hand and tool motions, occasionally blocked by the student's head or shoulder.

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Reveal what the student was doing during the substantial portion of his time when he was looking at the bungee without acting, was reading the T.O., or otherwise was not visible on camera 6.

Prevent the instructor from wondering why the screen was vacant, or whether or not someone was active in the work area.

Ambient hangar temperatures were in the range 70°-80° (Fahrenheit). Students complained of heat from the 600 watt lights. This problem would have been more serious later in the year, when normal afternoon hangar temperatures exceed 100°.

Camera 6 was later moved and installed on a lowboy mounting, to the forward side of the wing between gear and tank (6B, Figure 12). The near-ground mounting and advantageous angle of the wing allowed a clearer view of the bungee with less body interference. One light, placed at the former camera position (6A), gave adequate illumination with virtually no glare, but with occasional blocking by personnel movements.

7.1.5 Video Technique, 20-21 May In further tests conducted 20 and 21 May, camera 6 was moved to a position by the right gear wheel, looking up from the closest floor position at 11 o'clock to the task. Lighting was provided from in back of the wheel (see Figure 13), and camera 4 was again used on-call by remote control to provide a general view of trainee actions. Slightly improved picture resolution resulted. A recording was made on 22 May (see Appendix B, Video Sample Log 6). In this camera 6 position, the bolt on the rod end of the bungee (inboard) was partially obscured by hydraulic lines. It was observed that correct insertion of that bolt could be confirmed by observation of the position of the trainee's hands as he inserted the bolt. The bolt must be inserted from above, not below. This is a process rather than a product observation.

7.1.6 Instructor Evaluation On 17 May a group of 6 USAF instructors conducted testing experimentally, using video access. The instructors were seated at the console; one instructor operated the console as

necessary and scored performance, while the remaining five simply scored performance as seen on video. Students were instructed to come to the console area when they required guidance, or when the testing required the instructor to inspect a part (measure length of linkage, task 9, and check tightness of thumbscrews, task 13); otherwise all evaluations were made by video monitor access. Instructors were invited to comment on the adequacy and effectiveness of the system. These tests were conducted without use of the audio intercom. Portions of the test sequence were recorded; see Appendix B, Video Sample Log 3.

Table 7 summarizes this series of experiments. Student activity was displayed at the console through a changing sequence of monitors, special effects displays and recording techniques, while instructors scored the regularly scheduled block tests on the basis of video information. When it was possible to recognize scoring criteria through the video presentation without difficulty, and when all instructors agreed on the scoring, an X on the table indicates that the video subsystem which was then being used was fully acceptable. When the subsystem did not present acceptable information, when its use resulted in uncertain scoring, or when users made significant comments, a numeral on the table refers to an appropriate note.

7.2 TASK 2 - WING MOORING

7.2.1 Task Description The mooring task required tying the aircraft from mooring points outboard of the wing tanks, using a rope and either a bowline or a square knot.

7.2.2 Test Criteria The critical observation at the right wing was whether or not the student could tie a bowline correctly (as distinguished from other knots). The existing test required tying the right wing with a bowline and the left wing with a square knot. It was the bowline task which caused the greater difficulty, although students occasionally failed to discriminate a square knot from a granny knot.

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TABLE 7. EXPERIMENTAL SCORING OF PERFORMANCE TESTS BY
VIDEO - AILERON BUNGEE TASK

Subsystem used, Number of student subjects	Acceptability of video information, All Criteria*
Camera 6B (zoomed to detail) Camera 4 (general view) 3 subjects	X, 1
Camera 6B (zoomed to detail) 2 subjects	X, 2, 3
Camera 4 1 subject	4
SEG Display: Camera 4 quartered on Camera 6B 3 subjects	X, 5
SEG Display: Camera 4 and 6 (as above) Recorded VTR-1 3 subjects	X, 6, 7
SEG Display: Cameras 4 and 6 (as above) Recorded VTR-1 Fast playback 4 subjects	X, 7, 8
SEG Display: Cameras 4 and 6 (as above) Recorded VTR-1 Fast search to last frames; view by stop-frame 7 subjects	X, 7, 9, 10

* Notation: X - Criterion was discernable on video, and
instructors agreed on scoring.
1 - See note.

TABLE 7. NOTES

1. Camera 6 is accessed through the sequential switch (SEQ). Thus, while this experiment was in progress, the SEQ was set "manual", and the SEQ monitor committed full time. As a result, during the time no video access was possible for tasks 8 and 10, which also are accessed through the SEQ; neither could camera 7 be used to provide the general view for task 9. In any future redesign or modification of the system, supplemental switching should be considered to directly route these camera outputs (5, 6, 7, 8) to a SEG, or to the recorder inputs.
2. Since no general view of the area was available, instructors could see only tool and hand movements, and end-product conditions (bungee removal, bungee installed). Subjects spent much of their time passively looking at the task, sitting under the wing and looking at the T.O. or the removed bungee, or away from the area. Instructors were uneasy during the approximately 65% of the time when no activity was displayed at the monitor. In a task typically requiring 8-15 minutes, less than 3 minutes was required actually to remove and replace the bungee; some subjects spent another 3 minutes in waste or erroneous activity. As instructors became familiar with the procedures, inability to see the trainee disturbed them less, and they were content to score this task by the end condition viewed at the monitor. For this purpose they required video only on two occasions: (1) when the subject needed help (rarely), and (2) at completion of the task.
3. During this experiment, no audio intercom system was available. Later one audio station was installed in the task 1 area, with the expectation that scoring that task could be accomplished in ten seconds by switching a monitor to camera 6 on call from the student. That would have represented a work economy for the instructor, who had to walk to the work area, stoop under the wing, and examine the bungee approximately 1.5 times per trainee assigned the task.

A brief attempt to demonstrate this method on 18 June was not successful. In spite of instructions, trainees walked over to the instructors, or had difficulty in using the intercom. Instructors were confused because no good procedure existed by which to recognize which intercom station was calling. It is recommended that:

Instruction to call in at task completion be written into test documents.

Calling in at every task conclusion be practiced, to reduce the milling of trainees about the area and to ensure that operation of the call system is learned.

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TABLE 7. NOTES (CONT'D.)

Consideration be given, in any future redesign or modification of the system, to a buzzer-and-light call system which will identify the station calling.

4. It was not possible to see criterion product points using this camera, and no process criteria were identifiable in the task.
5. In the SEG display the bungee appeared laterally across the monitor face from upper right to lower left, with the general (camera 4) view inserted at upper left to occupy less than 20% of the tube face. Instructors preferred this presentation to all others used.
6. The fact that no action is occurring on camera during most of the viewing time becomes even more obvious when the performances are scored from recordings, after students have left the area.
7. This performance recorded; see Appendix B, Video Sample Log 3.
8. No loss of information resulted from speeded replay, although hand and tool movements were blurred.
9. It was clear that the task could be fully scored by viewing the end-product on a single static video frame. No process criteria were identified.
10. These are the same subjects and tape as those in the two entries immediately above. The tape was replayed to perform the evaluation.

Correct tension and slack in the line was also important, but realism of the test was impaired in this respect by the fact that the line was secured, not to a floor bolt, but to an eyebolt seated in a light, moveable wood block.

7.2.3 Observations This task was currently scored by an instructor who had to move to within view of, and closely observe the knot. The procedure was inefficient. Many students (most of those observed) had serious difficulty in tying a bowline, and spent much time in fruitless experiment; they then frequently presented an incorrect knot for evaluation, and required substantial remediation and several attempts before succeeding. It is doubtful that learning occurred, and certain that the testing procedure did not demonstrate competence. Several instances were observed in which an incorrectly tied knot was scored "correct", when seen cursorily at a distance. This would appear to be a point at which video might:

- Provide early clues, feedback and remediation to prevent practice of error behavior.

- Reduce instructor movement.

- Speed trainee performance.

- Provide speedy and precise inspection of product, and prevent reinforcement of error.

7.2.4 Video Technique Mooring tasks were readily observable by panning and zooming camera 4 to either wing area. At the right wing, ambient lighting was fully satisfactory. At the left wing, artificial lighting would have been required if actual evaluation were attempted. Evaluations during the study were limited to the right wing. Incident light at the best plane of illumination normal to the axis of the ropes was (sunny condition) 65 footcandles right, 20 footcandles left; see lighting charts, Figures 14 and 15.

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7.2.5 Split Screen Display A SEG-2 display was constructed in which the monitor screen was split vertically and shared with task 1, the aileron bungee. Since it was necessary to see only the rope to verify correct mooring, and since that required only a narrow vertical slice of the screen, the SEG display was constructed with the rope occupying only the right 1/4 of the screen and with the bungee displayed obliquely across the remaining 3/4. Criterion features of both tasks were adequately visible.

7.3 TASK 5 - WHEEL BRAKE TRAINER

7.3.1 Task Description A wheel and brake assembly was mounted separately as a mock-up trainer, which at the time of this study was located to the rear and right of the aircraft. The student was required to remove the wheel, then the brake assembly, and to replace them both on the hub correctly.

7.3.2 Test Criteria Formally recognized test criteria were:

Criterion 1 - Reinstalling the wheel with its inboard and outboard sides correctly positioned.

Criterion 2 - Proper position of a drain.

Criterion 3 - Alignment of keyways and splines.

Criterion 4 - Connection of an air hose.

Criterion 5 - Proper seating of a wheel nut.

7.3.3 Observations Of the listed criteria, number 1 (wheel position) could be verified by an observer from either the back or front of the trainer. Criteria 2, 3, and 4 were visible only from the back (strut) side. Criterion 5 was visible only from the front. The task raised interesting videotechnical and performance measurement problems, concerning the number of cameras required to collect all needed information, the possibility of integrating that information into a single signal using special effects, and questions of the relative necessity of product and process measures.

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It appeared that the 5 product criteria listed above were not fully adequate to assess a trainee's knowledge of the task, since it was possible to assemble the wheel and brake correctly by accident. There was a 50 percent chance of mounting it right side inboard, 20 percent chance of properly positioning the drain, and roughly a 15 percent chance of proper alignment of splines. A possible process measurement point was observing whether the student looks over the wheel while sliding it on the drum, which he must do to see the splines. (See further paragraph 7.3.7.)

7.3.4 Video Technique, 16-18 May The diagram at 5 on Figures 12 and 13 represents the trainer, which consisted of a stand on which was mounted a wheel strut, wheel and brake assembly.

Because both sides of the wheel had to be examined to recognize criterion performance, cameras 1 and 4 were initially set up to see their respective sides of the wheel (Figure 12).

Camera 1 was placed at azimuth 11 o'clock from the trainer, distance 12 feet, and zoomed to frame the wheel plus approximately 18 inches each side and 3 feet above. Illumination was ambient light from the hangar door (behind the camera) only. A highly satisfactory signal was presented at the monitor, using maximum iris opening.

Camera 4 was positioned high at 7 o'clock and approximately 12 feet distance, framing (initially) the same area as camera 1 from the opposite side of the trainer. Lighting from the hangar doors (facing the camera) was more intense than lighting on the work surface, and caused wash-out images at low iris openings, or glare which blocked out working detail at high openings. Using the remote iris control, it was possible to achieve adequate resolution of the wheel and of trainee actions, but a poor picture resulted. Iris settings required frequent adjustment due to changes in light angle with time of the day; the remote capability was valuable in that regard. A 600 watt incandescent light was positioned at 5 o'clock azimuth, 8 feet from the wheel,

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lighting the dark side so that a high quality picture was produced at camera 4. In spite of reduced iris openings using the light, at the end of the working day a persistent after-image of the hangar door had been formed on the vidicon screen, an image which lasted for about 40 minutes after the camera had been trained on a different target.

Critical details of the wheel discernible from the camera 4 side were only two: correct position of inboard and outboard sides, and seating of the axle hex nut. Therefore, camera 4 was later zoomed in, and refocused to frame only the hub, the nut, and its immediate area of approximately 16 inches square. In this setting the highlight from the hangar door did not interfere seriously with contrast and resolution, and adequate pictures were possible without artificial lights.

Still later, camera 2 was detached from another task (2A, Figure 12) and positioned low (18 inches above floor) at near 12 o'clock azimuth (2B, Figure 12). It was used to monitor details of the wheel and brake face, while camera 1 monitored general trainee movements and camera 4 monitored the hub and nut. Finally, camera 2 was zoomed in further to frame only the lower right 1/3 of the wheel. This increased the clarity of detail and still included all criterion points on the monitor screen. Recordings of student performance were made in the course of this experiment; see Appendix B, Video Sample Log 2. Later roles of these cameras were reversed: Camera 2 gave the general view, camera 1 was zoomed to detail. In summary:

Camera 1 monitored the strut side of the trainer, seeing the wheel plus surrounding activity from the light side. This camera normally faced the trainee, from the opposite side of the trainer, as he worked. When the wheel was fully mounted, the trainee's body was partially obscured by the wheel.

Camera 2 monitored details of the wheel from the same side.

Camera 4 monitored criterion 5, the wheel nut and hub, from the opposite, dark side of the wheel. When the trainee was working, he normally had his back to the camera, obscuring the wheel nut about 50% of the time.

Camera 4 was used at the same time by remote pan/tilt to cover tasks 1, 2, 5, and 11.

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Using camera 2 to provide a general display of the trainer and of trainee movement, a SEG-1 display was produced using output of camera 1 to display details of spline alignment, wheel position and hose attachment, with output of camera 4 inserted (quartered) in the upper right and zoomed in to show detail of the wheel nut only. This display was highly effective. All criterion points were identifiable from the SEG display.

A problem was identified in use of the SEG: When this display was attempted using ambient lighting, adequate pictures were seen at the monitors for both cameras 1 and 4, but when those signals were combined on the SEG, the high signal level from camera 1 tended to control the AVC level, and blocked the signal from camera 4, which framed the less well lighted side of the wheel assembly. The result was that, in any display in which the horizontal scan passed from camera 1 to camera 4 (all quartered or vertically split displays), the camera 4 segment was darkened and its resolution badly degraded. A light was placed at azimuth 8 o'clock (Figure 12), 8 feet from the wheel hub, and resulted in an excellent SEG display, in which the small shadows and highlights from the unshaded bulb brought details of the hub and nut sharply into definition in spite of the small area (less than 20% of screen) of the quartered camera 4 SEG display.

A SEG-1 display was generated using a horizontally divided screen, on which camera 1 presented, at the bottom, the lower half only of the wheel assembly. The output of SEG-2 was used to insert above, in the left quarter, the wheel nut (camera 4) and in the right quarter the general view from camera 2. This display was generally satisfactory, although the reduced image size of the camera 2 display, and cascading of the signal, reduced the resolution of detail from camera 2. A more serious deficiency was that, in some instances, it was not possible to see the hose attachment.

A SEG-1 display was generated in which camera 1 presented the lower half of the wheel (as above), and camera 4 output, including the wheel

nut, was presented on the upper half of the SEG monitor screen. This display was technically successful to the extent that it made it possible to present both sides of the wheel in a single display without using artificial light. The blocking effect noted earlier did not occur when cameras were combined on the SEG split horizontally (top and bottom). This display was marginally defective because (again) the hose connection occasionally was not visible. An attempt was made to use the remote zoom capability of camera 4 to provide, alternately, a detailed view of the wheel nut and a general view of the trainer and trainee actions. While it was possible to do so, it proved impractical. Under certain (midday) lighting conditions it was necessary to reset iris openings after each change of zoom. In any case, it proved difficult to operate the zoom rapidly enough to respond to the alternating need for detailed and panoramic information.

7.3.5 Video Techniques, 21-22 May Further tests were conducted 21 and 22 May. Camera layouts for that test are illustrated on Figure 13, and differed from earlier layouts only in that camera 2 had been removed to another task. Camera 1 was zoomed to frame approximately the lower 3/4 of the wheel and brake assembly, showing all possible positions of the hose line and other criterion points visible from the strut side. Camera 4 was moved slightly to the left (up in diagram, clockwise in relation to the task) so that it could frame the entire trainer but avoid the glazed area of the hangar doors. In morning light there was some glare from the hangar floor, which caused a washed-out image and unclear presentation of the wheel nut. This could be corrected either by using supplemental lighting or by remotely zooming to verify seating of the nut.

7.3.6 Instructor Evaluations Evaluations by the instructors on 17 and 18 May produced the following findings:

Additional Criteria The product criteria formally identified (7.3.1) proved to be incomplete, and additional criteria were discovered

which, although they had not been documented, were actually being used in scoring the task. New criteria were:

Order of tasks: The order of tasks directed by the T.O. required that the pneumatic line be connected after the brake assembly was installed, but before the wheel was mounted. That sequence was important for flight safety, but could not be verified by inspecting the completed task. Existing practice made it a matter of chance, or of instructor habit, as to whether an intermediate check was performed - to make such a check required the instructor to walk to the back of the trainer - and most failures to meet this criterion went unnoticed. The video test, however, made access to the rear of the trainer readily available, and differences in the scoring practices of the instructors became obvious.

Spline matching: The possibility that the wheel might be installed with splines and keyways correctly aligned by accident has been noted. To mount the wheel correctly (and safely) the mechanic had to look over the wheel while sliding it on, and rotate the wheel to match the splines. Confirming this behavior required a process observation.

Wheel seating: One subject was observed to fail to seat the wheel completely over the brake assembly. In this position, all visual check points appeared correct to a casual inspection through the video monitors, although the defect would have been obvious on direct inspection. Placement of cameras so as to view the work more obliquely, or use of strong oblique lighting, would have made this criterion more readily visible.

The consequence of identifying these additional criteria was to increase the number of criteria to 8, of which 5 were formal criteria previously listed:

Criterion 1.	Wheel placement	(product)
Criterion 2.	Drain position	(product)
Criterion 3.	Spline alignment	(product)
Criterion 4.	Pneumatic hose	(product)
Criterion 5.	Wheel nut seating	(product)
Criterion 6.	(new) Order of tasks	(process)
Criterion 7.	(new) Spline matching	(process)
Criterion 8.	(new) Wheel seating	(product)

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Experimental Scoring Table 8, which follows, summarizes results of experimental scoring of the wheel-brake task, in terms of the separate performance and product criteria. Notes include pertinent comments by the participating USAF instructors. Portions of this test were recorded; see Appendix B, Video Sample Log 2.

7.4 TASK 9 - DOOR LINKAGE

7.4.1 Task Description This task was located under the left wing, inboard of the tank pylon, where a small fairing door was attached by a linkage the length of which could be varied by turning a threaded coupling. In the gear-down aircraft, the linkage was below and outside the wing surface. It was obstructed to some degree, from every angle, by the fairing door or other structures.

7.4.2 Test Criteria Test criteria were:

Properly adjusted length of the linkage, measured by a ruler.

Attachment of the proper ends to proper points.

Insertion of a pin (one end) with head up.

Insertion of a bolt (other end) with head up.

7.4.3 Observations This task was of technical interest because of the difficulty of visual access, physical smallness of critical parts, and extremely poor lighting of the area under the left wing (less than 2 candle power at task, see Figure 14).

7.4.4 Video Technique, 16-18 May Initial attempts were made to observe removal and replacement of the door linkage from the front end of the wing tank near the leading edge of the wing. This area was quite dark; ambient lighting at the task (point A in Figure 15) was less than 2 footcandles. Light was placed in various positions around the tank, the fuselage and in front of the wing. In every case, severe highlights from the aluminum surfaces of the aircraft tended to block out monitor

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**TABLE 8. EXPERIMENTAL SCORING OF PERFORMANCE TESTS
BY VIDEO — WHEEL-BRAKE TASK**

Subsystem used Number of student subjects	Criterion scored							
	1	2	3	4	5	6	7	8
Camera 1 general view Camera 2 zoomed Camera 4 zoomed 2 subjects	X	X	X	X	X	X	X	1
Camera 1 zoomed Camera 4 remote zoom 1 subject	X	X	X	X	X	X	X	2
Camera 1 zoomed Camera 4 on call remote 1 subject	X	4	4	4	5	X	6	1
Camera 1 1 subject	X	4	4	4	7	X	6	1
SEC Display (A) Camera 4 quartered on Camera 2; Camera 1 on monitor 2 subjects	X	X	X	X	9	X	X	1
SEC Display (B) Camera 2 & 4 quartered at top, Camera 1 at bottom 1 subject	X	X	X	10	11	X	X	1
SEC Display (C) Camera 4 50% super- imposed on Camera 2 1 subject	X	X	X	10	X	X	12	1
SEC Display (A) Recorded 1 subject	13	X	X	X	X	12	X	1
(continued)								

* Notation: X - Criterion was discernable on video, and instructors agreed on scoring.

1 - See note.

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TABLE 8. (CONT'D.)

	1	2	3	4	5	6	7	8
SEG Display (A) Recorded selectively 1 subject	14	14	14	14	14	12	14	1
SEG Display (A) Recorded at slow tape speed (normal) action 1 subject	15	X	X	X	X	12	X	1
SEG Display (A) Recorded with speeded replay 1 subject	16	X	X	X	X	12	X	1
SEG Display (A) Recorded and replayed using stop-frame feature 1 subject	17	X	X	X	X	12	X	1

TABLE 8. NOTES

1. No occasion of improper wheel seating occurred.
2. An occasion of improper wheel seating occurred. One instructor recognized it from video evidence. All instructors agreed that the error could not be reliably observed through the monitors.
3. Camera 4 was zoomed back for a general view except when inspecting for criterion 5 (wheel nut). Wheel nut placement was not visible in ambient light, except by zooming to maximum detail.
4. This single frame, zoomed view gave adequate resolution of the drain hole, pneumatic hose, and splines. Subject movements were confusing, because data presented at the monitor were limited to hand and tool movements. Those movements seemed incoherent when larger body movements were not clearly known, or were blocking the monitor view. When camera 1 was zoomed back to where body movements were coherent, criterion detail points were not clearly discernable.

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5. Camera 4 was not used except on call, to verify wheel nut placement (criterion 5); therefore no monitor was available through which the instructors could see a general view of the trainer and of trainee actions. Instructors were uneasy during those times they could not see the trainee - typically the times he was looking at the work or studying the T.O.
6. With no camera offering a general view of the trainer (comment #5) it was not possible to anticipate exactly when the trainee would begin to mount the wheel. When he did begin, the instructor-console operator began to pan remote control camera #4 to cover this criterion, but by the time the action came into focus the trainee had completed mounting the wheel. This (criterion 7) is the process criterion which was more effectively scored from the camera 2 position, anyway, since the trainee was facing that camera while mounting the wheel. He could be seen (if he performed correctly) to look over the wheel, to rotate it until the splines matched, and then to slide it into place over the drum.
7. Criterion not visible.
8. All criteria were clearly visible in spite of slight image loss due to cascading. Camera 4 presented only the wheel nut, and its output was set to obscure less than a quarter of the camera 2 screen. Since camera 4 was remotely controlled, no difficulty was experienced by the operator in recentering the frame for use of the SEG display.
9. When used without artificial light the SEG display was unsuccessful. Low gain signal from camera 4 resulted in near total darkening of the corner display and corresponding wash-out of the camera 2 image. Artificial lighting on the wheel nut corrected this condition.
10. Only the lower half of the strut side of brake and wheel was visible, and not all possible positions of hose attachment could be seen.
11. The wheel nut was clearly discernible but detail was washed out due to multiple cascading (camera 4 to SEG-2 to SEG-1).
12. With no overall view it was not possible to verify this process.
13. Quality of information was satisfactory but was slightly degraded by recording. Instructors could see no reason for ever using this procedure, found reviewing the recording tedious, and missed evaluation points due to inattention. This followed long periods during which the trainee was passive, reading the T.O., or off-camera. Actual time spent in significant activity was less than 1.5 minutes in a task which took (typically) 12-15 minutes to complete. (When

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monitoring activity not recorded, several activities were in progress at any time and the instructors found their attention more fully engaged.)

14. It proved impossible to turn the recorder on at appropriate times so as to most economically record all criterion detail (reference note 13 above).
15. Slow (economy) tape speed produced a slightly jerky image, but instructors saw no loss of information content.
16. Speeded replay produced a saving in evaluation time with no loss of information content. The attention problem in reviewing the tape (see 13 above) was less serious because periods of inactivity were brief.
17. Criterion features were recognizable in stopped-frames. Instructors saw no need, in this task, for the stop-frame capability, since criterion features were fully visible during speeded replay. Attempts to use the "fast forward" between stop-frame points did not produce any saving in time.

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images and threatened to damage the camera tubes. It appeared for a while that no combination of camera and light positions would be found which would at the same time be free of unacceptable glare, resolve criterion details of the task, and not interfere with performances of the trainee. Positions of camera and lights immediately below the task were videotechnically acceptable but obstructed the work. Similar lighting difficulty is certain to occur in any use of the video system around aircraft: Because of the highly reflective surfaces it is difficult to obtain good lighting, and there is a constant hazard to vidicon tubes from stray spots of glare.

The videotechnical problem was solved, initially, by camera 2 positioned at 2A on Figure 12, with a light actually at ground level (lying on the floor) at 8 o'clock from the work, under the wing tank at about 6 feet. A diffuser on the light did little to relieve glare, but adjustment of the barn door eliminated reflectance from the landing gear strut, and paper taped to the underside of the wing eliminated an area of glare from that point. Camera 2, in this position, faced the trainee as he worked on the task and was able to monitor criterion features at the two ends of the linkage, although intervening structures obscured the center of that linkage and most of its length.

Next, camera 3 was mounted on a lowboy tripod, and positioned by the wing tank at 18 inches from floor level, 5 feet from the linkage, and 7 o'clock azimuth (Figure 13). This camera viewed the trainee's actions from his left as he worked, and gave a slightly clearer and closer view of the linkage. It was hoped that, from this position, camera 3 could be remotely controlled to observe elements of tasks 1, 2, 8, and 10. This proved infeasible for two reasons:

In lowboy mounting, movement in azimuth is limited by interference between camera or lens and the tripod legs.

In panning, the camera tended to pick up points of reflectance from the aircraft, and was hard to relocate exactly on the task while avoiding bad highlights from the underwing and tank side.

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It was observed that the remote camera in lowboy mounting is very precariously balanced, since the mounting point and center of gravity is close to the outer legs, and the remote control unit is heavy. In fact, in panning the camera remotely it would be easy to create enough tension on the cables to overturn the camera. Two precautions were observed:

Shortening the back leg of the tripod tended to restore the center of gravity.

Passing cables back over the tripod and wing tank created a counter tension on camera and tripod. We would have preferred to safety-wire or guy the tripod to some secure point.

After some experimentation in recording, attempting special effects, and evaluation of options by the instructors, it was determined that camera 2 was unproductive, and it was moved from 2A to 2B. Camera 3 was first set to frame an area approximately 30 x 30 inches around the task, an area in which movements of the trainee's upper body, head, hands and tools could be seen with only occasional blocking of the work by his head or shoulders. It was later found possible to zoom in on the task to frame an area approximately 12 x 12 inches, in which the linkage appeared laterally across the monitor screen from lower left to upper right, with criterion features clearly observable.

As happened in the cases of tasks 1 and 5, USAF instructors participating as evaluators found that they were able to score existing tests fully by using only the close-in, detailed view of the task and observation of the criterion product points. This condition was met by camera 3 as its most detailed focus. Nevertheless, as in tasks 1 and 5, instructors felt uneasy, and expressed dissatisfaction that they were unable to see a broader view. They wanted to see the trainee's movements, to have a general view of the task area, and to know what the trainee was doing when off-camera. Much of this off-camera time the trainee spent in the immediate area, studying the tech order, selecting tools, manipulating and inspecting parts, or studying the task area from a point a foot or two off the monitor frame. Camera 7

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was therefore taken from another task and position at 7B (Figure 12) so as to view the work area more broadly, from the rear of the aircraft and looking over the tail.

A special effect was constructed on SEG-2, in which the output of camera 3 displayed the linkage, and output of camera 7 was inserted in a lower corner of the screen. Typically a check of the SEG-2 monitor would show the student studying the T.O., and only occasionally taking action to remove, replace, or correct errors at the linkage.

A difficulty was identified: Since access to camera 7 is through the sequential switch, it is necessary to stop cycling of that switch, and use it in the manual mode in order to set up a special effect using camera 7. This makes outputs of cameras 5, 6, and 8 not available so long as the special effect is displayed. In any second generation video system, consideration should be given to including an alternative switching arrangement.

It was observed that, as they gained experience and confidence in video monitoring, instructors felt less demand for a general view of the task area, and were more willing to score on the basis of product criterion features, or in other words on the basis of the detail view presented from camera 3 and without the panoramic view framed by camera 7.

7.4.5 Instructor Evaluations On 17 May a group of 6 USAF instructors conducted experimental testing on this task using the procedure outlined at 7.1.6 and 7.3.6. Table 9 summarizes that experiment.

7.5 TASK 10 - RUDDER BUNGEE

7.5.1 Task Description An artificial feel bungee for the rudder control system was located high in the tail surface, with access from the left side. The access panel was permanently removed. A number of

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TABLE 9. EXPERIMENTAL SCORING OF PERFORMANCE TESTS
BY VIDEO -- DOOR LINKAGE

Subsystem used	Acceptability of video information
Number of student subjects	All criteria*
Camera 3 Camera 2A Camera 7 1 subject	X, 1
Camera 3 Camera 7 1 subject	X, 2, 3
Camera 2 Recorded, VTR 2 1 subject	X, 3, 4
Camera 2 Recorded, VTR 3 Fast playback 1 subject	X, 3, 4, 5, 6
SEG Display: Camera 3 (detail) Camera 7 (general view) 1 subject	X, 5, 7

- * Notation: X - Criterion was discernable on video, and
instructors agreed on scoring.
1 - See note.

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TABLE 9. NOTES

1. Having identical information displayed by cameras 2 and 3, from different angles, actually proved confusing.
2. The subject worked with his body between camera and task area. The effect was periodic blocking out of the monitor, followed by static display of the task hardware. It was possible to score the tests fully in this mode.
3. This performance was recorded. See Appendix, Video Sample Log, Tape 1.
4. Instructors saw no reason why the test would ever need to be recorded. Scoring the test from the recording made it more than previously obvious that process criteria were not involved, and that criterion performance could be recognized from the final hardware condition when the task was complete.
5. No information was lost by fast playback.
6. Additional lighting was provided to a total of 1200 watts. Subject complained of the heat.
7. Instructors preferred this display, in which a general view of trainee actions was inserted, quartered at the corner of the monitor screen, to other presentations. This preference was felt by the instructors long after they became accustomed to not seeing trainee gross actions and in spite of the fact that they could not explain what information they acquired from seeing those actions. We presume that the general view is used to orient detail in its relation to larger perceived events. That is, the mental processing by which observers relate the small details seen on a monitor are perceived in relation to the total aircraft is assisted by having a monitor presentation which offers intermediate scale orienting information.

hydraulic lines, control linkages and other structures were present which confused an observer trying to monitor this task from the ground.

7.5.2 Test Criteria Same as for the wing bungee (1).

7.5.3 Observation This task was experimentally interesting, in part because it involved high access, use of stands, avoidance of improper footings, and potential safety violations.

7.5.4 Video Technique Camera 5 was set up against the wing tank and at 7 o'clock to the task, viewing the rudder bungee. A fully satisfactory monitor presentation was achieved without difficulty, using ambient light. A 500 watt incandescent hangar light was located over this area, slightly forward, to the left and above the tail. Unfortunately no student was assigned to the rudder bungee task during the time of this study.

7.6 TASK 11 - STABILIZER BOLTS

7.6.1 Task Description The right stabilizer was fastened to the aircraft frame by three heavy bolts, the heads of which were visible (panel removed) in the upper surface at the root of the stabilizer. These bolts required installation of safety wire.

7.6.2 Test Criteria Proper safety wiring of bolt heads.

7.6.3 Observations The task was selected for study, but like task 10 above was not performed by students during the time of video experiments.

7.6.4 Video Technique Camera 4 was remotely controllable to view the stabilizer bolts, which were easily visible in ambient light.

When lights were in use in task 1, precautions had to be taken to shield the direct line between these lights and the camera as it panned through the area.

7.7 TASK 12 - CHUTE RELEASE

7.7.1 Task Description A drag chute compartment was located to the lower left of the fuselage under the tail. It was checked by closing and fastening the compartment doors, working from the rear of the aircraft near ground level, and then pulling the drag chute release cable from the cockpit to observe that the spring-loaded chute doors popped open.

7.7.2 Test Criteria That the doors lock, and open when the release is pulled.

7.7.3 Observations The student performance was experimentally uninteresting (no failures or difficulties were observed). It was included in study for its video-technical interest.

7.7.4 Video Technique On 21 and 22 May this task was recorded using camera 2 from directly behind the aircraft (azimuth 6 o'clock to the task), on lowboy mounting at 8 feet, ambient lighting. A performance sample was recorded; see Appendix B, Video Sample Log 6.

7.8 TASK 13 - FUEL FILTER

7.8.1 Task Description A door in the belly of the aircraft gave access to the interior of the fuselage at the engine compartment (the engine was removed). Just inside the door, against the fuselage wall at the lower right, a large fuel filter lay horizontally. The trainee task was to remove the filter from its housing, then remove and replace the filter element.

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F-100 AIRCRAFT MAINTENANCE TRAINER

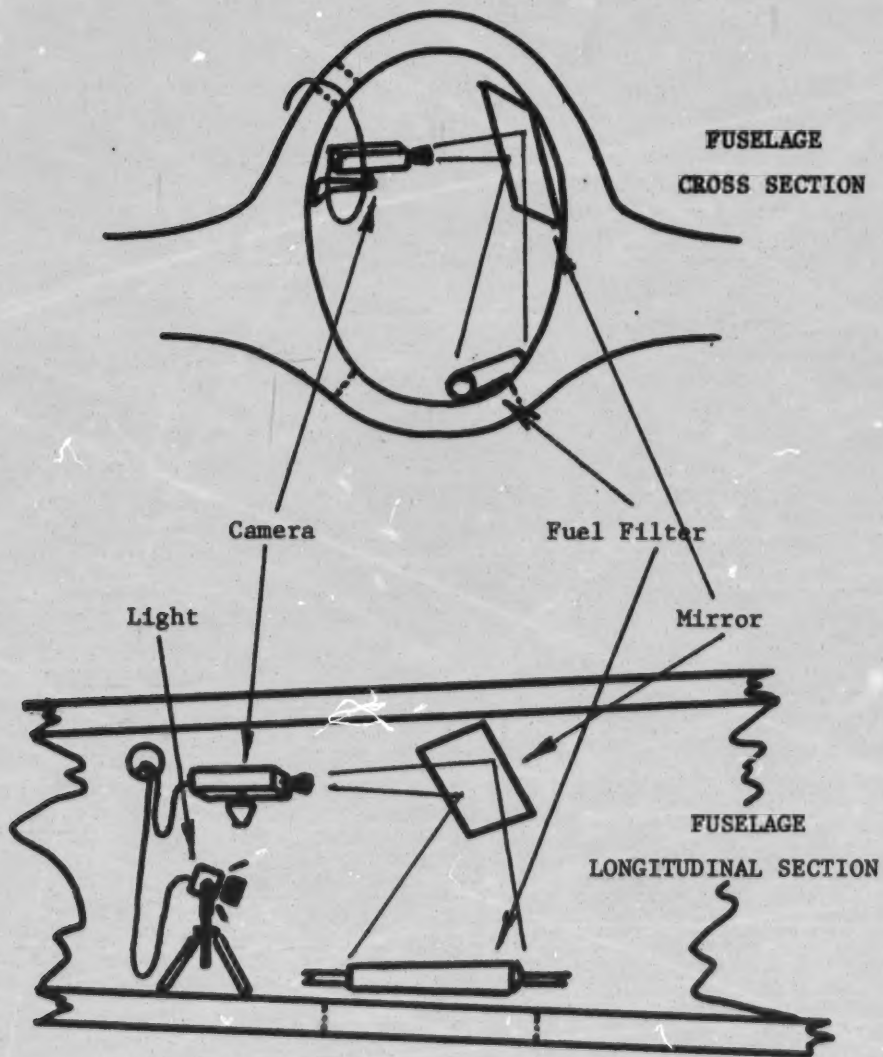


Figure 16 - Fuel Filter Task

7.8.2 Test Criteria Test criteria were:

Successfully removing the filter.

Proper torque of a wing nut in reinserting the element.

Successfully replacing the filter.

7.8.3 Observations This task was of high interest because:

The task was highly inaccessible. To see it the instructor had to crawl under the aircraft and stand up through the access panel (removed). He could not do so until the student moved out. See Figures 12 and 16.

There was no measurable ambient light at the task.

There was no readily apparent place to position a camera or lights.

When being performed, the work was largely obstructed by the student's body and hands.

The test was highly uneconomical of time and effort.

Instructors habitually avoided observing the completed task; they had the student bring the filter element to them, examined seating and torque of the wing nut, and assumed successful reassembly of the filter without inspecting it. When first observed, the filter was loose, presumably because the last trainee had not completed the task properly.

7.8.4 Video Technique Viewing this task presented special difficulties. Not only was it inside the fuselage at a point with no light, but a man working on the filter obscured it almost totally with his head and body.

An initial attempt was made to monitor the task through a mirror mounted just forward of the task, right of the centerline of the aircraft, and high in the engine compartment. Camera 7 was positioned looking into the open tail and focusing on the mirror (7A, Figure 12). Several difficulties remained:

Although the filter was clearly visible through the mirror, the distance was too great to provide acceptable resolution.

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The only locations at which a light could be placed to illuminate the task either interfered with performance of the task, interposed a light between camera and mirror, or faced a light into the camera.

The task was largely obstructed, during its performance, by the student's left arm and shoulder.

In a second attempt, the mirror was placed over the task and closer to the compartment wall, and the camera was mounted to the opposite wall of the compartment (Figure 16). Excellent resolution of the task was achieved, and the work was only occasionally screened by head movements. Viewed through the monitor the image was reversed and inverted, but hands and tool movements still seemed natural and were easily interpreted. The effect was that of a view from above. In this circumstance, the psychological effects of the mirror view were minimized. Inversion of the image resulted in a presentation in which the subject was at the top of the screen and the work at the bottom, but because the view was from overhead it appeared quite normal. This was true in spite of the fact that, with left-right reversal, the filter appeared to be installed in a reversed position. This caused little confusion to the observers (who rarely saw the filter anyway) once they recognized and expected that the aft end of the filter would appear at the left of the screen.

7.9 MISCELLANEOUS TASK - TRIPOD JACK

On May 22, recordings were made of students operating a tripod jack, shown at the lower right on Figure 13. Camera 5B was positioned as shown at the lower right. Recordings were made using ambient light.

7.10 SEQ EXPERIMENTS

Utility of the sequential switch (SEQ) was studied by a series of experiments in which student performance was scored by observing the sequential display of two or more camera outputs. Five USAF instructors observed student activity, and attempted to score tests by observing

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the sequentially cycling outputs of from 2 to 4 cameras. Cameras 5, 6, 7 and 8 were used, under control of the SEQ, at various rates of speed, and under varying conditions of control. Conditions under which it was (or was not) possible to score tests were recorded, and comments of the instructors were elicited in regard to the utility and limitations of this kind of observation.

Observed were activity at the tripod jack (camera 5), the aileron bungee (camera 6), the door linkage (camera 7) and the fuel filter (camera 8). In addition, simulation of SEQ display of a complex task was performed by manual switching the outputs of cameras 1 and 2, (the wheel/brake assembly), presented as a two-part special effects display. The findings of this experiment were:

7.10.1 Distraction It was possible to monitor activity while the switch ran sequentially. To do so could be distracting. It was much more distracting to cycle through four cameras than three, and not at all distracting to alternate two.

7.10.2 Fast Cycling Rates If it was desired to attend to only one task, it was possible to do so with the cycling rate set high (about 1-1.5 seconds per frame) so that an observer could at any moment effectively retain in memory a pictorial image of the last pertinent frame seen, for comparison with the next. At these cycling rates, all observers were able to effectively disregard two intervening frames (from other cameras), and most were able to disregard the three intervening frames of a full SEQ 4-frame cycle. The question was whether there was any point in making such observations; if it were desired to attend to only one task it seemed easier simply to use one camera, continuously presented, using the SEQ in the manual switching mode.

7.10.3 Intermediate Cycling Rates At cycling rates between 1.5 and 4 seconds/frame it was not possible to observe criterion task

features effectively. Such short times of exposure did not permit the observer to perform the optical orientation, criterion detail search, and intellectual processing needed to make a criterion judgement during a single frame; neither was it dependably possible to retain an image in memory while waiting for the pertinent frame (camera output) to reappear.

7.10.4 Slow Cycling Rates At cycling rates between 4 and 7 seconds per frame it was again possible for observers to visually analyze any one preselected activity, and to recognize any single criterion condition. This was true provided the observer did not attempt to attend to more than one activity (camera output). Most instructors participating in the experiment were able to recognize more than one criterion during a 4 to 7 second frame exposure. Thus, they could perceive and analyze all three criteria for bungee installation in about 4 seconds. They were not able to do the same for the eight criteria on the wheel-brake task in less than about 12 seconds. Presumably that much time is required for successive cycles of criterion recall (remembering what is to be looked for), visual search, and mental processing.

7.10.5 Very Slow Cycling Rates At cycling rates about 8-10 seconds per frame, instructors were able to continuously and sequentially observe and evaluate the outputs of all 4 cameras as they were presented on the SEQ monitor. That is, they were able, as each successive task came onto the monitor screen, to recall the criteria to be observed, to recognize the proper-improper condition of those criteria (except on the complex wheel-brake task), and to score the tests on that basis. However, doing so continuously was impossible. Persons attempting to do so eventually became confused, fatigued, and unable to tolerate the pressure of the task. It was not until the time of frame exposure was raised to about 20 seconds that continuous monitoring became tolerable.

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At these cycling rates (greater than 9 seconds/frame) the length of the total cycle is 32-60 seconds, and a disadvantage becomes apparent; A critical event can occur on any one camera and not be noticed. Thus a trainee might reverse and reinsert the door link pin (task 9) incorrectly without its being noticed, or begin an unsafe use of the tripod jack.

7.10.6 Prolonged Exposures At exposure rates of 20-30 seconds/frame it appeared feasible to continuously monitor 3-4 complex activities sequentially, as for instance in a safety inspection task. Such rates did not appear to be useful in testing. To score any particular item on a performance test might require, for instance, waiting up to 90 seconds in a 4 camera, 30 second/frame sequence. It was much more economical under those conditions to switch manually; instructors participating did in fact use the manual switch to access cameras selectively when they had specific test items to score.

7.10.7 Instructor Preference When offered the opportunity to select an optimal mode for use in test scoring, instructors selected a rapid cycling rate for task surveillance, and stopped the sequence manually to perform scoring. They set the SEQ at approximately 1.75 seconds per frame. At this rate they were able to maintain cognizance of which task sites were active, and to recognize, for instance, that the bungee had been removed or reinstalled. Any single change of state (as for instance reversal of an incorrectly inserted door hinge pin, task 9) could be recognized without manually stopping the sequence. Nevertheless they invariably elected to stop the sequence manually and to observe the task in a continuous presentation on the monitor while scoring test items.

The existing SEQ switching arrangement was a little uneconomical for this purpose. To switch manually to any frame it was necessary to: (1) Turn the function control from "sequential" to "manual". (2) Press the sequencing switch from 1 to 3 times to reach the desired camera

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output. In doing so, operators frequently inadvertently switched past the desired camera and had to press up to 7 times before achieving the desired presentation.

It would be useful to consider, in any future redesign of the system, an SEQ switching system in which each camera output is represented by an individual switch or button, which, when pressed, would temporarily override the sequential switching function.

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SECTION 8.0 POWER LINEMEN VIDEO TESTS

The second application of the Video Observation System to be examined was in the screening of candidates for the Power Linemen course in the Civil Engineering Department. Candidates for that course were given a pretest and an initial screening interview, to determine whether they could adapt to the work. The principle causes of failure in the course were lack of coordination and fear of height; therefore a pretest had been devised which involved having each candidate climb a 50 foot pole equipped with climbing steps ("the tower") and a 25 foot pole using climbing spikes strapped to the legs. Subject performance was observed, and a judgement was made as to the subject's willingness, confidence and "trainability". If these qualities were not exhibited to the satisfaction of the evaluator, who was an experienced instructor, the candidate was rejected.

8.1 OPERATIONAL CONFIGURATION

The video equipment to be used in this application was disconnected from the full console, set up, and placed in the back of a 2 1/2 ton truck which served as the operational location. The truck was, of course, necessary to transport the equipment, but served further to simulate a remote location. Ultimately, such a system would (presumably) be installed in a fixed office location, but such an installation would have been too expensive and time consuming to construct for purposes of this test. The equipment configuration was that described in paragraph 5.1.2, with VTR-3 added. It included two remotely controlled cameras, three recorders, and an equipment bay in which were two camera monitors, the switching group, the remote camera controls, two special effects generators, and audio mixers (not used). The equipment configuration is illustrated by Figure 20.

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Two remote-control cameras were employed so that a split screen with a close up, plus an overall perspective view of the climber and pole could be obtained.

Approximately three hours were required to disconnect the required equipment, load it on the truck, transport it one mile, and connect it up for operation. This required two technicians and two laborers. The truck used had a power lift tailgate, which was essential for safe movement of the rack mounted equipment.

A 120 volt outdoor outlet had been installed near where the truck was parked for the purpose of furnishing power to the system. No other special arrangements were necessary. The relative location of the truck and test area is shown in Figure 17.

8.2 TEST PROCEDURE

Once the equipment was set up, the senior NCO who was to operate the system was given an orientation on the equipment. His duties consisted of operating the two remote cameras (zoom, iris, focus and pan/tilt), the intercom (push to talk), and one tape recorder (remote control). The monitor screen was split in half vertically by a SEG display, with the close up view on the left and the overall view on the right. After approximately thirty minutes of orientation and practice the NCO was familiar with the equipment, and from that point controlled the operation himself.

On the day of the demonstration, seven students were to be tested. Normally they would have been tested on the poles by one NCO instructor, and subsequently interviewed by the senior NCO of the department. He would have available test results in the form of qualitative statements and recommendations by the NCO who had administered the test. For purposes of this system tryout, the senior NCO was present in the truck, observing and video recording each candidate's performance. The NCO instructor in the field with the students controlled their activities in

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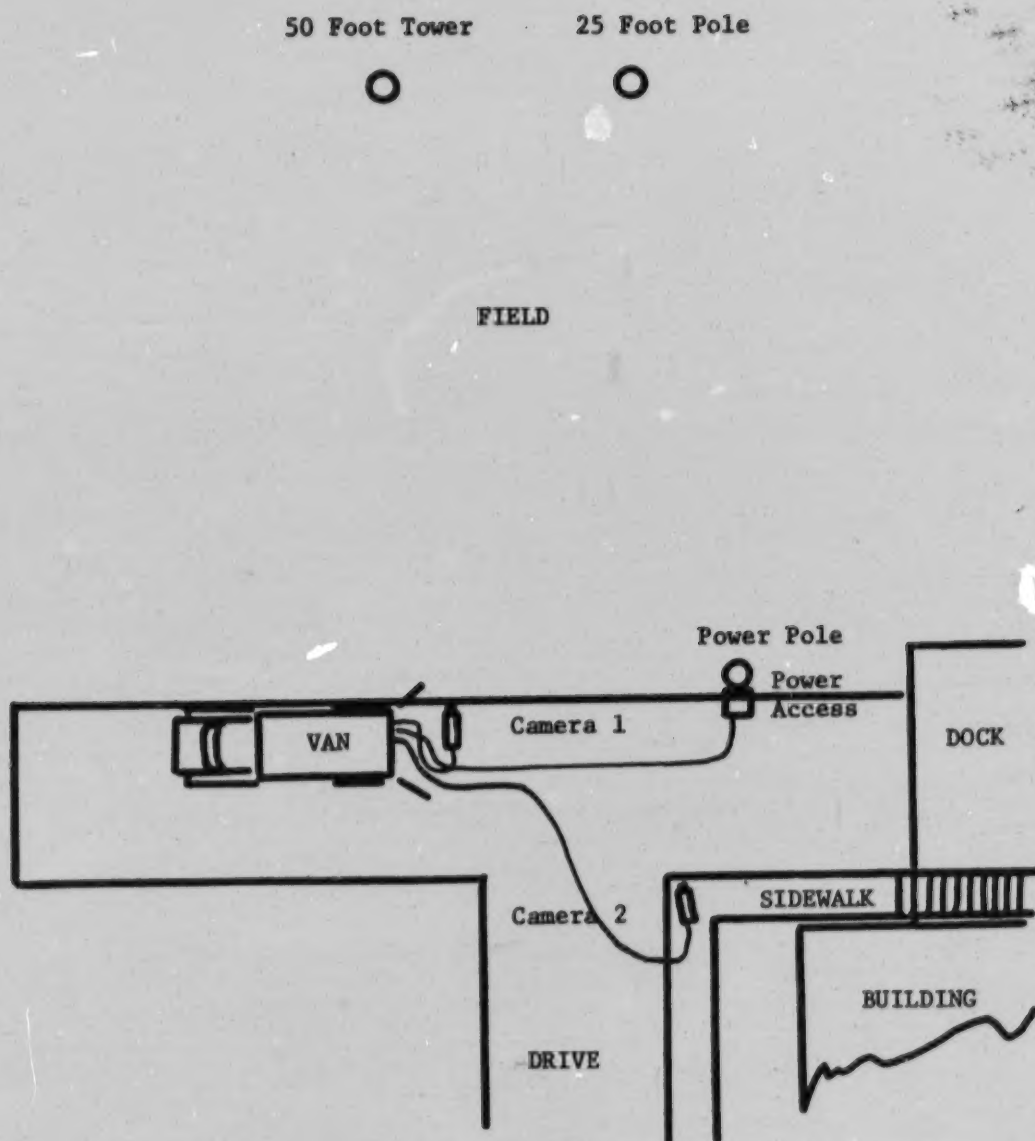


Figure 17 - Field Layout - Pole Climbing Task

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accordance with instruction he received over the intercom from the senior NCO. During testing the senior NCO observed the candidate's performance, and recorded his comments and evaluation (as audio) on the video tape. A permanent record therefore was obtained of each student's performance, and of the evaluation made at that time.

8.3 OBSERVATIONS

The tryout of the system showed that:

8.3.1 The remote camera which provided an overall view of the subject's performance seldom needed to be adjusted, and could have been a fixed position camera.

8.3.2 Viewing the subjects performance through the video monitor was as effective as viewing the actual performance, and offered a better view of specific actions.

8.3.3 The most useful view of the climber was one which framed his whole body on the screen, while he was climbing the pole from the side opposite the camera.

8.3.4 Evaluators paid little attention to the output of the fixed position camera which monitored the whole pole (perspective view) while the subject was climbing.

8.3.5 The subject could be tracked up the pole, using the remote control camera, with no difficulty.

8.3.6 Changing light conditions (clouds passing in front of the sun) required frequent adjustment of the iris setting, which was critical in the bright light. The remote control capability was vital in that regard.

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8.3.7 The optimum placement of the camera from a lighting standpoint was on a line from the sun to the target. This might mean that any operational location of the camera would have to be dependent upon the time of day that testing was to be performed.

8.3.8 Independent evaluations of candidate performance, based on review of tape recorded performance (with the audio track comments turned off), produced consistent evaluations.

8.3.9 The slow and speeded motion capability of the Javelin recorder offered no advantage to this application, while the remote control capability of the Panasonic VTR was useful from a control standpoint.

8.3.10 It would have been desirable to have the capability to record instructions being given the subject, by the NCO instructor, as the student attempted to climb the poles. This would have been feasible with the present system, but was not recognized as desirable in sufficient time to permit setting the microphones and cabling up.

8.3.11 The performance tapes were reviewed by personnel from the Psychiatric Counseling office, who indicated that such records could be of value in their dealing with student personnel who, later in training, report themselves to be developing fear of climbing.

8.4 CONCLUSIONS

8.4.1 The system provided a capability for real time evaluation of student performance, and for recording such performance either for later evaluation or as a permanent record of student performance.

8.4.2 Operation of the system is easily learned, and does not interfere with the evaluation process.

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8.4.3 A functional system could be designed for this application that would cost approximately \$5,000 for equipment and installation. It would consist basically of one remote control camera and lens, one VTR, and one monitor, plus two way communications.

8.4.4 It is recommended that a basic equipment system be secured and installed for this application.

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SECTION 9.0 INSTRUCTOR TRAINING VIDEO TEST

The last exercise conducted by URS/Matrix during the field test was an experimental use of the Video Observation System to record the performance of Technical Instructor trainees during practice teaching. The purpose of this exercise was to determine the utility of the video system in the training and evaluation of new instructor personnel. The advantage foreseen was that it would permit the recording of instructor performance in front of an actual class, with simultaneous recording of student reactions. This was to be done using fixed cameras and a split screen display. A feature of interest in this application of the system was that it was to require no operator personnel other than the instructor himself. The instructor was to turn the system on, teach his class, and then remove the tape and take it to his supervisor for review and critique. In this way the instructor's performance before an actual class could be evaluated by supervisory personnel without their having to be available at the time the class was actually given, having to review the total presentation, or intruding into the classroom. It was anticipated that such a system would offer an improved method of evaluating instructor personnel, and administrative advantages.

9.1 THE OPERATIONAL CONFIGURATION

The classroom available for testing this application of the system was in the Civil Engineering Department at Sheppard AFB, Texas (as was the Power Linemen pretest evaluation). The classroom used was designed for practical work as well as lecture presentation, and there were individual work stalls along the side and rear of the room. Students used these stalls to practice the electrical conduit installation procedures which they were being taught. For purposes of our evaluation, only the

lecture portion of the presentations was taped, since the practical work portion of the training was a problem akin to that which had already been investigated in the Jet Mechanic testing area.

The system configuration used was the partial console used in the Power Linemen test (Figure 2), with audio mixers actively employed and fixed cameras. The physical arrangement of the equipment is shown in Figure 18. Camera 1, in front of the classroom, was equipped with a wide-angle lens that covered all of the students. Camera 2 was focused on the instructor's podium, and the adjacent area to the instructor's right. This camera covered the instructor as he moved back and forth in front of the class and as he used the blackboard. Desk microphones were placed around the room between each group of two students; five microphones covered the ten students in the class. Cables from the cameras and microphones were strung along the floor, under a door, and across the hall to another room where the console, recorders, and monitors were located. This arrangement minimized distraction to students and instructor; and made the system as non-intrusive as possible.

9.2 TEST PROCEDURE

The scope of this test was greatly limited by unexpected changes in school scheduling, as a result of which only a single student instructor was available as a test subject. Approximately two hours of lecture presentation material was recorded using this instructor trainee as the subject. In addition, a half-hour period of practical work by the students at their desks was recorded, to explore the possible value of evaluating instructor performance during such an exercise. This portion was not planned, but was conducted since it occurred in the normal course of the class being observed.

The recorded performance tapes were reviewed and critiqued by several different groups. These included the instructor himself, his supervisor in the department in which he was assigned, and personnel from the Instructor Training Department. The student instructor was asked what

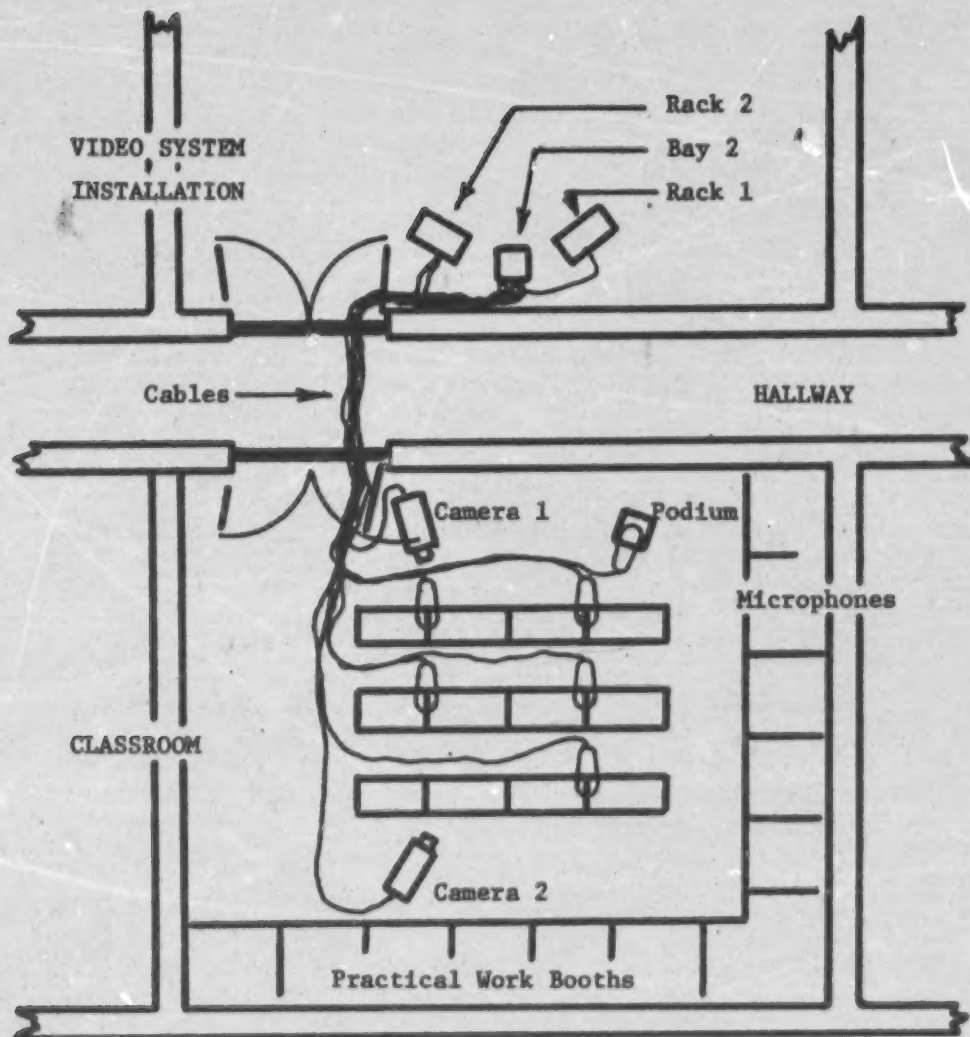


Figure 18 - Classroom Layout

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information about his performance he could discern from the recording, and whether being filmed in front of a live audience, and being able to review the students reactions, was of any significant value to him. The instructor indicated that he found the film useful, and as a result intended to change several aspects of his performance and presentation. He felt that he had exhibited nervousness as a result of being recorded. He said he recognized his performance as being overly stiff and formal, and that this was due to the presence of the cameras and his concern for how his students might react to the situation. He said that he was gradually becoming accustomed to the notion of being recorded, and that in another session or two probably would be able to ignore the equipment.

Supervisory personnel from the instructor's department were asked to review files to see if there were any new aspects of instructor performance that they could discern which were not previously observed, and whether they could adequately evaluate instructor performance by viewing a recorded sample performance. Two supervisors who viewed the tape independently both felt that evaluating on a sampling basis (e.g. moving from one portion of the tape to another for a total viewing time of 15-20 minutes) was not adequate. They felt that they might have missed something which would have affected their judgement one way or another. They were able, upon viewing the total presentation, to identify several technical errors.

As a result of this review, supervisory personnel expressed the possibility that it would be desirable to have all classrooms equipped with an observation capability which could be monitored from a central location. They felt that this would provide maximum quality control of instruction, with a minimum of intrusion into the instructional process. They did not feel that the recorded format, as an alternative to direct monitoring, offered any significant advantage from a scheduling or evaluation standpoint.

Tapes of the instructor presentation were also shown to senior personnel from the Instructor Training Department. These people had

originally suggested the requirement for some method of capturing instructor performance for later evaluation, since they had a responsibility to monitor the initial performance of graduates, after they were assigned to actual training duties in other departments of the school. This was difficult for them to accomplish due to the amount of time required, and to conflicts in schedule; therefore, they were interested in identifying means by which they could flexibly fit classroom observations into their schedule. However, between the time of specification of this requirement and the time of tryout, there had been a major reduction in the requirement for new instructors, and scheduling problems which had existed earlier were considerably reduced.

Upon reviewing selected portions of the tapes of instructor performances, the opinion of the Instructor Training personnel was that there was certainly enough information on the tape to make an accurate appraisal, and that an opportunity to view the student simultaneously with the instructor was essential. The utility of the system was acknowledged in terms of the original parameters that they had laid down; the question of where to install such a system, however, was difficult. The Instructor Training Department trains instructors for all departments of the school, so new instructors give their initial classes in a wide number of locations. Any one location for the equipment would be unsatisfactory, multiple installations would be too expensive, and using a portable system would not provide the manpower savings benefits that were the basis for the requirement in the first place. While the concept was useful in terms of the quality of information returned, logistics made it infeasible to apply under the current mode of operation.

The possibility of permanently installing some type of observation system in classrooms was discussed with Instructor Training Department personnel. It was their view that such systems would be very undesirable from the student instructor's standpoint, and might make personnel unwilling to become instructors. The idea of not knowing when you were being observed was unacceptable.

The aim of this experiment was to create an operator-free application in which the instructor would simply start, stop, and change tapes on the equipment. Nevertheless during this brief test, URS/Matrix project personnel did interact with the equipment during videotaping, in order to determine what the optimum control settings were, what mix of camera views was most useful, and what quality of recording was being obtained.

The most useful combination of views recorded was a split screen (SEG) image, with the instructor appearing at the top of the picture and an overall panoramic view of the students shown at the bottom. Recording the output of the special effects generator in this manner provided a constant, synchronized presentation of instructor actions and student reactions. Several different combinations of display were tried and evaluated. A corner insert of the instructor proved to be satisfactory, and provided a broader view of activity in the classroom, but the instructor tended to move out of the field of view more readily. A vertically split display was of no value, since it did not provide the necessary panoramic view of the students. The horizontally split display proved most useful, and the best division of the screen was approximately two to one, with the top third devoted to the instructor (head and shoulders) and the bottom two-thirds showing the students.

Sound recording proved a problem due to uncontrolled noise. The microphones were high quality, sensitive, and of the cardioid-pattern type. As used sitting on the desk tops, however, two things happened: First, since they were pointing toward the ceiling, the microphones picked up high frequency noise from the air conditioning vents. Second, some students had the habit of tapping a pencil on the desk top, causing vibrations which were virtually indiscernible to the instructor, but transmitted noise into the audio channel. A better installation of the microphones would be to mount them overhead, pointing down toward the students; fewer microphones could then provide better coverage and pick-up. Such an installation was not feasible to attempt within the time of this tryout.

9.3 FINDINGS

Based on observations by the project team and by assisting USAF personnel, the Video Observation System has a potential for application in the training of instructors. Its utility to the instructor trainee, in reviewing his own performance, is clear. Less clear is its value for use by supervisors.

The use of video recording as a means by which an instructor can be given feedback from his own performance, after that performance and while not under pressures of the classroom, is a recognized technique which has been demonstrated repeatedly by other experiments. This experiment demonstrated the effectiveness of the Video System for that application. Furthermore:

The simultaneous recording and display of class members with their responses substantially increased the usefulness of the procedure.

The use of a SEG generated, split-screen display made it possible to see both instructor and student data in a single video channel, and to record that data economically on tape.

The use of slow tape speed to conserve tape did not substantially detract from the procedure.

An instructor can perform the procedure without assistance of a video technician, starting and stopping the recording himself.

The value of video as it might be used by supervisors was not clearly established. The system is technically effective for this purpose, and can make it possible for supervisors either to monitor classroom events remotely or to review them at a later time. That those capabilities have potential payoffs is assumed, but it is not clear how those capabilities can properly be applied. It appeared from the test that:

The system is technically effective.

For review by supervisors, a view of the class in addition to the instructor is at least optimal, and possibly essential.

Use of the system as a supervisory tool in the existing school at Sheppard AFB offers no net advantage. The payoffs do not warrant the cost.

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It is not clear under what circumstances supervisory personnel might find recording more economic than real-time monitoring.

It is clear that a substantial consideration, in planning real-time monitoring, is the probability that instructors will object to its intrusiveness.

SECTION 10.0 FINDINGS

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Findings and observations made during the Phase III field tests are summarized in this section. Notes in brackets [] identify questions investigated, and refer to the decimal coding of Appendix A. Notes in parentheses () identify paragraphs of this report at which findings were reported in narrative.

10.1 INSTRUCTION AND EVALUATION - JET AIRCRAFT AREA

10.1.1 Process/Product Content [Question 1.1]

Testing procedures observed in use on the F-100 aircraft maintenance trainer were based on objective scoring of product criterion measures. It should be emphasized that these tests were highly developed measures, in which each point of evaluation had been derived from analysis of an end-product hardware condition which a mechanic must achieve - from the observable conditions of a ready-to-fly aircraft. The tests did not ask how those conditions were achieved; they asked only whether the end product conformed with the technical order. Thus the testing procedure would appear to have eliminated any possibility that the processes by which maintenance tasks were performed were worth observing (6.0)(7.0).

It is emphasized that these tests were professionally made and administered, reflected advanced theories of instruction, and were mission effective. Nevertheless URS/Matrix personnel identified at least three respects in which their rationale was defective or inconsistent: First, we found that technical instructors actually applied criteria which were not formally written into the tests, but which they recognized as important (as in the case of unstated criteria for the wheel-brake assembly (7.3.1 and 7.3.6). Secondly, there were certain measures which were in

fact made by observing processes, as in the case of the bearing lubrication task (6.3.1, Task 6). In this regard it was found that trainees could (and sometimes did) assemble tasks 1, 5, or 9 correctly by accident, without being aware of the criteria for correct assembly. Instructors were aware of that possibility, and compensated for it by asking informal questions of the form "how do you know that . . .?" questions which, although not part of the written test, were in fact considered in scoring. Practice in this regard varied widely from one instructor to another, and from case to case.

[Question 1.1.1] Critical Product Points:

Product criterion points for each subtask are identified in Section 6.0.

[Question 1.1.2] Feasibility of Video Scoring:

Most criteria were feasible to monitor through the video system. In general, criteria which were ordinarily scored by visual inspection were readily scored either by direct video monitoring or from video recordings. Minor failures occurred, as in the case of failure to perceive an incompletely seated wheel assembly (7.3.3). Some criteria were not customarily scored by visual inspection. For instance in the fuel filter task, tension of a thumb screen was checked by feel (7.8). In this case video scoring was achievable by directing the trainee, through the intercom, to display the filter, test the thumb screw tension and describe what he was doing. A few criteria, not scored by observing product conditions, were not fitted to video monitoring. The inspection of landing gear door locks (6.3.1, Task 4) was made visually by the trainee, who recorded his findings on his test sheet. Observing the trainee looking at the doors was pointless. So was looking at the doors, for their mechanical defects were deliberately built into the trainer and were known to the evaluators. The trainee's correct marking of the test was evidence of correct inspection.

[Question 1.1.3] Gain/Loss in Precision using Video:

When technical difficulties had been solved, no criteria (normally scored by visual inspection) were identified which were scored less precisely using video. The wheel seating perception referred to earlier (7.3.3), was easily made once lighting had been improved or the camera sited at a more oblique angle. Every formally expressed test criterion could, in fact, be scored with perfect precision either from the student's response or from the completed task. Video neither reduced nor improved the precision of that scoring. However:

There were a few cases (discussed later at 10.1.2) where the technical quality of the image was reduced after recording or multiple cascading.

A few (mostly unstated) criteria which were process rather than product measures were more readily observed using video than otherwise,

[Question 1.1.4] Gain/Loss in Economy using Video:

Economy of instructor effort appeared to be a principle gain achievable by the use of video. Because tasks were distributed about the aircraft, many in places difficult to observe or access (cockpit, underwing, engine compartment), there were at least 11 points in the test at which the instructor nominally was required to move to the point of maintenance and perform a visual inspection. If the first check discovered an error, a second check would be required, and for a class of ten students the instructor was expected to make 120 or more determinations in this manner. This was logistically impractical. Instructors evaded the requirement by avoiding some tasks (fuel filter, rudder bungee), and by short cutting others. They made casual or long range inspection of the aileron bungee, mooring knots, and fuel filter, or accepted verbal assurance that those tasks were complete. As a result, during the time of the URS/Matrix experiments, they accepted incorrect performances on each of these tasks.

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The video tests demonstrated that all visual judgement involved could be made from the video console by a seated instructor, at substantial savings in time and effort.

A by-product of such measurement was greater effective precision of measurement, since criterion details were presented at the monitor in optimum scale, focus and lighting. Errors were unlikely to be overlooked, and every completed task was reasonably assured of inspection.

Some economy and improved precision might, in theory, be achieved using video recording. If a task can be recorded it might be feasible to score it later, possibly when time might be saved or a more careful judgement made. In practice this did not appear to be the case. Reviewing recorded material was uneconomic because of the time lost in logging, manipulating recorders, and searching the tape. No instance was seen when a better judgement might be made later, and participating USAF instructors could not foresee circumstances in which recording would offer an advantage.

Further precision of measurement would be achievable by formally scoring process points.

[Question 1.1.5] Process Measurements:

Process measures were identified, the inclusion of which either would improve the testing procedure (7.2) or would formalize and systematize an existing unregulated procedure (7.3) (7.6) (7.8). Video access would make such measures practically feasible. Required would be a mechanism by which the instructor can be alerted, so that he can attend to the activity as it occurs. This might be accomplished, for instance, by instructions written into the test which require the student to call in on the intercom before mounting the wheel on the brake drum (Task 5).

10.1.2 Student/Evaluator Feedback

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[Question 1.2.1] Adequacy of Remediation:

Practice was vulnerable to criticism, at a few points, in that it resulted in poor learning experience. This occurred in instances in which, due to inadequate feedback from the instructor, students repeatedly practiced error behavior or were unable to recognize the criteria for correct performance at the completion of the task. Students were observed attempting to tie knots for the mooring task without effective models or guidance (7.2), and other tasks occasionally led to random experimentation not productive of learning goals (7.2) (7.3). This comment does not criticize the many cases in which student performance depended on the study of clear instruction given in the Tech Order.

[Question 1.2.2] Audio Feedback:

Video surveillance with audio communication could facilitate the recognition of students who are having trouble, and make it logistically possible for the instructor to intervene. The existing intercom system, however, is poorly suited for such a task, because it does not permit opening a discrete private audio link to any one student.

10.1.3 Time

[Questions 1.3.1 and 1.3.2] Time Required for Verifying Tasks:

It was not possible to time individual subtasks during this test, and the limited student sample would in any case have yielded unreliable data, but it was possible to make some general observations. Nominally, each verification of a subtask which requires a visual inspection should require the instructor to walk to the point of inspection (mean time not less than 10 seconds), make an observation (nearly instantaneous), speak to the subject or mark his test (8 seconds) and return, for a mean transaction time of 28 seconds (7.1). Typical tasks were completed in about 1.5 tries; when the task was incorrect on the first try, inspection took longer, and reinspection was required, raising the mean time per student

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per subtask to somewhat over a minute, not less than $3/4$ of which was spent walking to the task. Had this practice been actually followed, tests could not have been conducted in the time allotted.

Actually observed practice was less formal, more economical, but less reliable (10.1.1). Counting instances in which the instructors made cursory inspection at a distance or accepted student opinion that subtasks were correct, actual instructor time spent per subtask was probably close to $1/2$ minute. Instructors had other duties, of course, and not all tasks required visual inspection at the aircraft.

[Questions 1.3.3, 1.3.4, 1.3.5] Time Required using Video:

Some economy of time was achieved using the video monitor. In fact, most video inspections were too rapid to be measured, and in video monitoring the instructor's time was consumed mostly in waiting for criterion points to be reached. As was noted at 10.1.1, increased precision of test scoring was a by-product of this condition. Using an optimized video system, a single instructor could probably administer a test to a class of doubled size, conduct a test with twice as many visual measurement points, or conduct tests in two different areas at the same time.

For remediation performed before the end of a task, a saving in time resulted, again from the instructor's not being required to move. He could, for instance, note from inappropriate hand movements that the bolts were being installed incorrectly in the aileron bungee (7.1), and redirect the performance. Once again the principle advantage was not in the time saved for the instructor, but in the fact that because his time and motion was saved he could:

Continuously monitor several subtasks, and actually recognize error performance more frequently and sooner.

Redirect more performances per unit time.

Prevent inadvertent drilling of error behavior.

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A limitation on video capability in this regard was that many remediations cannot be made from the video console. It was easy enough to verbally redirect the bungee and door linkage tasks, where most errors were wrong binary choices - but for the student who could not tie a bowline knot in the wing mooring task, there was no way to assist him except by going to the task and handling the rope.

[Question 1.1.5] Recording Performance:

No economy or advantage could be identified which would result from recording student performance and scoring it later.

[Question 1.1.6] Work Samples for Instructor Training and Reliability of Test Administration:

A major anticipated benefit of the Video Observation System is its capacity to record performance samples, which can be used to familiarize instructors with correct and incorrect performances, to practice test scoring procedures, and to standardize their scoring of response behavior. This is a recognized technique for improving the reliability of human performance measures. Work samples were recorded with the intention of attempting to apply the technique in the Jet Mechanic course; this proved infeasible for one primary reason: The existing tests, when scored according to the nominal procedure, are fully objective and based on clearly defined product criterion measures (10.1.1). The scoring of each condition is clear, unequivocal, and not dependent on judgement; there is no requirement for a special standardization procedure. However, certain process criteria were recognized either as being informally used in scoring, or as desirable to consider (10.1.1). Only a few brief samples of such behaviors occurred in the material recorded, not enough to provide a useful experiment. If a sufficient number of these were assembled, and tapes were edited to eliminate non-significant activity, a valuable experiment would be feasible.

10.2 INSTRUCTION AND EVALUATION - POWER LINEMEN PRETEST

10.2.1 Process/Product Content [Question 1.1.1]

The two performances being evaluated by this task were similar pole-climbing tasks in which process judgements alone were important. Whether a subject climbed a pole was not the question so much as whether, in doing so, he exhibited the qualities of "confidence," "coordination," "willingness" and freedom from fear. These were subjective judgements based exclusively on process observation.

[Questions 1.1.2, 1.1.3, 1.1.4, 1.1.5] Video Capability:

All features of the task normally used in evaluation were fully monitorable by video, either in direct monitor or record/reply mode. No loss of precision was identifiable from use of video. Gains in discrimination were potentially achievable in that the zoom capability made a better angle and magnification of facial features possible, but during the test high sky-skin contrast (bright sky lighting) resulted in darkening of faces, and the detail of facial expression was no better than that visible by an observer under the pole.

10.2.2 Feedback [Questions 1.2.1 and 1.2.2]

Existing procedures required an experienced instructor on the ground at the pole to supervise administration of the pretest, to advise and direct performance of the task, and to ensure safety of the climber, assisting him, if necessary, to descend. This feedback could not have been performed from the video console. A live instructor was essential at the pole.

10.2.3 Time [Questions 1.3.1 through 1.3.5]

No gain or loss of time resulted from video monitoring.

10.2.4 Test Reliability [Question 1.4]

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Test reliability and reproducibility of the test procedure could probably benefit from comparative study of recorded performances. The reliability of the test, as conducted depended altogether on the subjective, predictive judgement of a few experienced instructors. These instructors were observed to differ in their evaluations of individuals. Given a suitable library of tape recorded performances, those tapes could be used to:

Compare judgements from one evaluator to another, rationalize the basis for those judgements, and standardize evaluator scoring practice.

Familiarize new test administrators with the procedure, to ensure that predictive results can be reproduced in the future, and to standardize the test across time.

Study pretest scoring longitudinally, by correlating scores with scores in training. Particularly, by studying cases of later failure in training to improve the predictive value of the pretest.

A further use for recorded performance was suggested by the school staff. For those students who later in training declare fear of climbing, or who are suspected of deliberate failure, the tapes may be of value in psychiatric counseling. Personnel from the mental health clinic who viewed the tapes concurred in that opinion.

10.3 INSTRUCTION AND EVALUATION - INSTRUCTOR TRAINING

10.3.1 Process/Product Content [Question 1.1.1]

Classroom teaching is a complex and demanding performance, the evaluation of which requires attention to a stream of simultaneous events, including the behaviors of students. Teaching performance is difficult to critique fully because of its complexity; it is difficult to assess objectively, and particularly difficult for an instructor himself to observe. The product measure of instructor performance is student

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learning; any specific brief observation is necessarily limited to assessment of process.

10.3.2 Video Capability [Questions 1.1.3 through 1.1.5]

Video monitoring was able to provide all essential details of instructor performance. A gain was recognized in that the presence of a TV camera was less intrusive than a live observer. A limitation was that, with a single fixed camera, the instructor could not move freely about the room without going off-camera. Video reproduction, both on direct monitor and record/replay, was quite adequate to reproduce all video detail of interest. Audio was noisy during the tests, but that noise resulted from a correctable technical problem (9.0).

10.3.3 Time [Questions 1.3.1 through 1.3.5]

No gain or loss of time resulted from video monitoring.

10.3.4 Recorded Evaluations [Question 1.4]

The single student sample which was available to record during this test could not provide the basis for any experimental test. Nevertheless the instructor concerned, two supervisors, and senior members of the training department all were able to recognize a potential value for recorded samples of instructor performance.

The value of recordings as a tool by which the instructor can review his own performance, with or without evaluation by a supervisor, is generally recognized. The capability to record student reactions simultaneously proved useful in this regard.

Selected samples of student (teacher) performance could be useful as standardization tools, to increase uniformity and reliability of supervisor judgement in scoring teacher performance, or in training supervisors in techniques of evaluation and critique.

10.4 VIDEOTECHNICAL CAPABILITIES

10.4.1 Video Feasibility - Jet Aircraft Area

[Question 2.1.1] Camera Access:

In general, the feasibility of camera access for all tasks studied was demonstrated. There were technical problems in the jet aircraft task which were of particular interest, and we will suggest long-term camera access solutions which are more desirable than those used in the field test. The area around the aircraft trainer was restricted and crowded; points important to video monitoring were frequently points which required unusual angles of view or which were in cramped spaces. Most importantly, the hardware being examined was typically positioned among other parts and assemblies which confused the video presentation, or obstructed the direct view. All these conditions made the jet aircraft trainer a particularly challenging test of video technique.

Solutions were relatively straight-forward, and were achieved without difficulty except for problems with lighting (7.3) (7.4) (7.10), and with Task 13, inside the engine compartment (7.8). This relative ease of solution resulted in part from the use of a light, compact, simple but relatively high quality camera, in conjunction with a very good zoom lens.

In the actively used areas under wings and around the landing gear, problems were encountered due to the interference between floor-mounted cameras and personnel performing maintenance tasks. Thus a camera used to view the aileron bungee (Figure 12, camera 6B) prevented normal performance of the wheel chock task, and the decision not to monitor that task was due in part to the fact that the camera would have been in the way (6.3.1). This difficulty would not be particularly important in a permanent installation. In a permanent video monitoring system the cameras presumably would not be tripod mounted, but would be permanently mounted to the aircraft or other supports, enclosed to protect the

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cameras, and connected electrically by permanently installed wiring. Thus it would be possible to use the space above, below and within the wing tanks and the underface of the wing to mount cameras which would be completely out of the way, and yet achieve superior angles of view, for Tasks 1, 2, 3, 8, and 9 (Figure 12).

For access to confined and/or dark areas, more elaborate approaches are necessary. Task 13 (Fuel Filter, 7.8) required fixed mounting of a camera inside the aircraft and use of a mirror; had space not permitted that solution, provision could have been made (in a permanent installation) for letting the camera lens through a hole in the fuselage.

In areas where there is a confusion of parts competing for attention (7.1) (7.4) careful camera placement and lighting focus can assure the highlighting of criterion hardware features. In an extreme case, a permanent installation could include differential painting of significant and non-significant structures, or of parts and background.

Camera access in the pole climbing and instructor training tasks was not a problem.

In summary, URS/Matrix staff saw no situation in which a task, which can be examined by a live observer, would be impossible to access using the Video Observation System.

[Question 2.1.2] Obstructions:

The tasks studied in the aircraft maintenance area required trainees to use hands and tools in confined spaces, with the consequence that visual access was likely to be blocked by hands, tools or body. A person performing mechanical work against a flat surface (such as an aircraft fuselage) blocks the line of sight for approximately 90° , leaving only about a 45° oblique access angle on either side from which the work can be seen. In any case, the work is likely to be periodically blocked by hand movements, and it is difficult to select angles which will not at one time or another be completely obstructed. For example:

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Task 1 (Aileron Bungee) and Task 9 (Door Linkage) were typical tasks which could be viewed obliquely but still were occasionally obscured by a body, head or shoulder. It was possible, however, to view activity in progress more than 90% of the time, and in every case to recognize proper task completion.

Task 2 (Wing Mooring) was a particular problem, since a subject could tie the knot facing in any direction. It was necessary to direct the subject to face the camera.

Task 13, on the other hand, was a case in which, because access to the work was highly constrained to begin with, subjects were rarely able to move so as to restrict view from the camera.

[Question 2.1.3] Camera Requirements - Product Criteria:

For every single end-product criterion condition being tested (in the aircraft maintenance testing problem) it was possible to display that condition as the output of a single camera. In all cases but one (Task 5) it was possible to frame all criteria applying to the task on a single fixed camera.

In the one instance in which a single task was presented as two views from different angles, viewers found the additional information more confusing than helpful (Table 4, note 1).

In cases where remotely controlled cameras were used to view product criterion detail for more than one task (7.2) (7.3) (7.4), viewers found that to do so required a cumbersome process of remote search and focus, and the hazard of intercepting excessive levels of light.

In a case in which remote zoom was used to pick up a product criterion (7.3.4) viewers found it feasible but cumbersome to do so, since it was necessary each time to adjust the iris and focus as well as the focal length.

The one case in which more than one camera was required was that of the wheel-brake trainer (Task 5), a case in which several criterion details were concerned, located on both sides of the wheel assembly.

In the pole climbing and instructor training problems, process rather than product measures were involved.

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[Question 2.1.4] Camera Requirements - Process Observations:

The camera requirements just discussed, for viewing end-product conditions in aircraft maintenance, were undemanding and were normally met by single fixed cameras because they were defined by static hardware conditions. Process observations were more demanding.

In three instances, special provisions were made to provide a broader view of the task area than was nominally required to see criterion test features. These views, which showed the task in relation to its surroundings, were provided for Tasks 1, 5, and 9, largely because of a need expressed by instructors to see gross trainee movements and to "know what the students are doing" when they were not actually performing operations in the task area. Since students spent more time deciding what to do, studying the T.O., and orienting themselves in their problems than they spent actually working with tools, these activities were a principle monitoring need. In no case was it possible to furnish dependable video coverage of all these actions, since the students were free to move about as necessary. It was clearly pointless, moreover, to try to follow them about with the remote cameras during such activity. As a result there were substantial periods of time when it was not possible to know, from video, what any particular student was doing.

More directly critical to measurement objectives were certain processes which were identified during the field study as useful to observe. One of these was in the wing mooring task, where feedback during tying of the knot was desirable for pedagogic reasons (7.2). Once the subject was directed to face the camera, it was readily possible to frame his hands and their adjacent area by camera 4 (Figure 12), and zoom up to inspect the knot.

At the wheel brake trainer, the useful process measures were observing the sequence of tasks, and watching mounting of the wheel (7.3). Camera 2, in fixed mounting, was used to furnish this information reliably, as part of a SEG display.

Insertion of pins and bolts in the door linkage (7.4) was a more difficult problem. Hand movements could be used to ascertain the appropriate direction of insertion. Most trainees performed the action from the rear of the wing and thus were framed by camera 2; however it was possible to perform the same action from the other side of the assembly, in which case camera 2 saw only the trainees back, and camera 3 picked up the action (Figure 12). Thus for this action at least 2 cameras would be required to dependably observe bolt insertion, unless the trainee could somehow be constrained to face camera 2 only.

A very similar bolt insertion occurred at the aileron bungee (7.1), but in this case, although the trainee might be facing any of several directions, the high oblique angle of the camera to an overhead object made it possible for camera 6 to view the action in any event.

As was observed at 10.2.1, process measures were central in the pole climbing task. Two cameras were required, since it was desirable at the same time to have a closeup view of the subject as he climbed the pole, and to have a more general view from which to follow his progress and see his position relative to the ground. Both were remote control cameras because, for the closeup, it was necessary to follow the subject up the pole, and for the general view it was necessary to pan from pole to pole. In any case remote iris control proved critically important, because in the high lighting condition encountered, iris settings required constant adjustment.

As was observed at 10.3, process measures were observed in the instructor training problem, and two cameras were used: One to frame the instructor, and one with a wide-angle lens to view student reactions.

[Question 2.1.5] Lighting:

Lighting proved to be the most difficult and limiting condition. The Video System is supplied with 600 watt incandescent TV lights, which are adequate for most anticipated needs but which, during the aircraft

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maintenance tests, produced glare and sharp reflectances from the aluminum aircraft surfaces, bright enough that even brief exposures could have produced burns on the camera tubes (7.1) (7.6).

In general the video equipment produced adequate resolution of work detail, without artificial lighting, when ambient light was within the range 20-200 footcandles at working surfaces, and within distances of 5-25 feet. Work including fine detail, or very low ranges of monochrome contrast, required higher threshold levels of lighting.

Highlighted areas appearing within that range - at levels from 60-200 candle power depending on iris settings and size of the highlighted area, had the effect of degrading the image. Depending on how the signal was processed at the console, that degradation appeared as a wash-out, blackening, or loss of detail in the monitor presentation, resulting from the effects of amplification and automatic signal level control (7.1) (7.3).

Highlights which did not prevent adequate resolution of an image at first amplification, as shown by the camera monitor, caused degradation of the signal when it was processed by further switching, generation of special effects, or recording. In particular, signals from poorly lighted targets resulted in blanking or blackening of special effects (7.3) (Table 3, note 9). This means that artificial light may be required for recording or special effects, when for the same case it is not required in direct task monitoring.

Highlights could be controlled, normally, by control of illuminating sources or adjustment of camera position. Occasionally a single bright spot could simply be blocked or covered over. Glare from a wing tank surface was controlled by taping a piece of paper over the area concerned; in a permanent installation the same area might be covered with a matte finish paint.

The lights furnished with the video system had barn-door shutters, which could be used to shield areas of the target field from direct light,

and had screen diffusers to reduce glare. These excellent lights were designed for TV or cinema photography, and they produced highly desirable light and shadow contrasts on many surfaces. This was not an advantage in illuminating technical and mechanical targets, like an aircraft, which contain highly reflective surfaces. In such cases a more diffuse light source is indicated. It is recommended that, in designing any permanent training application around aircraft, special lighting be constructed using fluorescent tubes in diffusing fixtures.

When artificial lighting was used, students complained of discomfort due to heat (7.1) (Table 4, note 6). This is another problem which fluorescent lighting could relieve.

Background highlighting and bright spots were a different kind of problem. During the field tests, problems were experienced due to the appearance of overhead building lights in the picture field, and of sunlight glare from floors and windows. When the level reached about 200 candle power at the surface, a camera at maximum iris opening picked up enough highlight to result in an after-image persistent for about 40 minutes (7.3).

Regarding lighting see also 7.1, 7.2, 7.3, 7.6, 7.7, 7.8 and Table 7, note 3.

[Question 2.1.6] Resolution and Discrimination:

In all cases the system was able to provide levels of resolution and discrimination appropriate to the uses tested. Problems and observed limitations of the system included three of significant interest:

First, a problem of field contrast: At least two aircraft maintenance tasks - the aileron and rudder bungees, presented low contrast targets with a confusion of irrelevant detail. In both cases adequate resolution was achieved at the camera monitor when appropriate camera angles were found (7.1) (7.5). A different problem was presented by the pole climbing task, filmed out of doors in bright sunlight: At distances,

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a figure climbing the pole was seen almost as a black silhouette against the bright sky; even in closeup, facial expression was poorly visible against the contrasting brightness of sky. Future experiments might attempt using a red filter in such applications (8.0). Field contrast posed no problem in the classroom monitoring task (9.0).

There was also a problem of small detail: Small details were critical in aircraft maintenance Task 1 (bolt position in the aileron bungee), Task 5 (spline alignment and wheel seating) and in Task 9 (bolt and pin heads on the door linkage). Good resolution was achieved on significant details as small as 3/8 inches at a distance of 8 feet, and non-significant features of less than 1/10 inch could be distinguished, provided the light was good and the color contrast adequate. The single observed failure to resolve detail was a case in which one student failed to seat the wheel solidly, and the deficiency was not dependably visible at the monitor. It is concluded that some details might require enhancement by special lighting, camera angle, or painting details of the hardware.

A final problem was degradation in switching, special effects and recording: In recording and replay, the output of camera 5 (Task 10, rudder bungee) lacked resolution of detail. This resulted from the weaker and more diffuse light at the rudder surface, with an absence of defining highlight and shadow. It is concluded that, for some conditions of field contrast which can be adequately viewed by direct monitoring, additional light or other video technical enhancement may be required to produce a quality recording. Switching and special effects generation were observed, for all subject matter, to result in less severe signal degradation, especially for subject matter of low contrast.

10.4.2 Supporting Audio

[Question 1.2.2] Audio Monitor-Record:

No requirement was seen for the audio monitor-record capability in

the aircraft maintenance area. In fact, the high ambient noise in that area would effectively preclude sound recording.

It has been assumed that no need for audio would exist in the pole climbing task, except to identify content of the tapes. After observing that activity and monitoring it experimentally, that assumption changed. During the climb, an instructor on the ground gave instructions, guidance and encouragement which would have been useful to the record, and he could have provided student names. If a permanent installation were to be made, it is suggested that instructors might be given a hand or headset mike output which can be mixed into the audio record channel.

[Question 1.2.2] Intercom Capability:

The intercom was used, with only limited success, in attempts to control the stopping and starting of recording at critical sequence points (Table 7, note 3). Less formal but equally unsuccessful experimental use was attempted at the wheel trainer, in which trainees were asked to alert the console before beginning key activities. In both cases the procedure failed for a variety of reasons. Trainees were not familiar with the system; they had difficulty using it, forgot to call in, and preferred to come to the instructor anyway. Too many people were active in the area, and there was confusion at both the outstations and the console as to who was calling or being called. Nevertheless a clear need was seen for an intercom system to perform alerting tasks.

To optimize instructor time, each trainee should call in at those points in the sequence at which he either needs guidance or is ready for product evaluation. This would eliminate most need for continuous observation, and permit cameras not on continuous monitors (those on the SEQ) to be switched in as needed. Instructions to call in should be written into test documents (Table 7, note 4).

An example of successful use occurred at Task 13 (Fuel Filter). A student was directed to complete that task without bringing the filter

out for inspection. After completing removal of the filter he simulated changing the filter element, then called in. The console verified verbally that the element had been changed, asked the student to show the open end to the camera, and to demonstrate and describe correct "finger-tight" torque on the thumb screw. The student then reassembled the filter, and called in again to have it inspected.

Various alternatives to the present sound system might be considered. There is a need for the console to be able to recognize which station is calling. There may be a need to speak to more than one station at a time. For applications in which the sole need is to alert the console operator to an evaluation, a buzzer system might do as well as audio, or one-way audio might suffice. Finally, confusion and noise would be reduced if the audio stations (in a permanent installation) were plug-in points for individual headsets.

10.4.3 Subsystem Capabilities

[Question 2.3.1] Sequential Switch:

The Sequential Switch was useful under certain conditions for monitoring activity in progress, but in most cases seemed not to be the optimum means of camera access. In several cases the fact that access to cameras 5, 6, 7 and 8 was available only through the SEQ reduced the utility of those cameras. These findings are described in detail at paragraph 7.10.

[Question 2.3.2] Special Effects Generator:

The Special Effects Generators (SEG's) proved extremely valuable in condensing the information from two or more cameras for presentation within a single frame.

In aircraft maintenance tasks, a recurring need was expressed to at the same time see an overall view of the task or area, and the specific

details of the task. This was repeatedly achieved by inserting a small overall view, as a corner-screen display, on a frame containing the detailed task (7.1) (7.2) (7.3) (7.4) (Table 7, note 5) (Table 8, notes 9, 10, 11, and 12) (Table 9, note 7).

An experimental 3 camera display was generated in which three views of the wheel-brake task (7.3) were combined. Outputs of two cameras were combined on one SEG, and then cascaded as one input to the second SEG. The resulting display was effective but produced a degraded second-stage image (7.3).

In the pole climbing task, the SEG display made it possible to see the subject's general position on the pole at one side of the screen, juxtaposed to a closeup of the subject as he climbed the pole (8.0).

The generally observed tendency of signal quality to be reduced by successive switching and cascading (typical: camera 6 to SEG to SEG to switch group to Recorder 1) resulted in some reduction in information for any signal processed by a SEG. The results were most obvious when recorded - that is, a signal recorded directly from a camera had better picture quality on replay than the same signal recorded as a SEG display. Signals from poorly illuminated targets were particularly degraded by the SEG. In instances where a poorly lit target was inserted onto a strong signal, one or both suffered darkening, wash out, or blanking of detail (7.3).

On the other hand, SEG displays could effectively double the information content of recordings by combining two camera inputs in a single record channel (7.1) (7.2) (7.3) (7.4) (8.1). In the instructor training tasks, a SEG display was particularly effective. Success in that task (as intended) required a simultaneous view of instructor and of class reactions, within a single video channel. The display was horizontally divided with the instructor (head and shoulders) at the top, and class (wide angle) at the bottom (9.0).

[Question 2.2.3] Remote Pan/Tilt:

The remote pan/tilt capability was useful in tracking moving actions, and in adjusting camera angle to recenter the image for SEG displays. It was used less effectively to provide on-call video coverage by panning from one subtask to another.

In the aircraft maintenance task, cameras 3 and 4 were stationed so as to provide remotely controlled, on-call access to several subtasks. Camera 3, on lowboy mounting, was to have accessed features of Task 1, Task 2 at the left wing, Tasks 8, 9, and 10. Camera 4 was to have accessed Task 1 in overall perspective, Task 2 at the right wing, the wheel side of Task 5, and Task 11. It did not prove possible to use camera 3 as planned, in part because the lowboy mounting did not give sufficient clearance around the tripod legs to permit free motion of the pan/tilt mechanism. There was danger of damaging or breaking off the lens assembly by torquing it against a leg, or of upsetting the tripod by shifting its balance (7.4).

In attempting to remotely direct camera 3 toward the rudder bungee (Task 10) a new danger was identified. It was possible to inadvertently pan across intense light sources (such as the 600 watt lamps) and to damage the vidicon tubes (7.4). In outdoor use (8.0), there was the corresponding and more serious danger of directing a camera towards the sun.

Remote control was particularly valuable in constructing SEG presentations. To center the appropriate action on that part of the camera frame which was inserted onto the SEG display, it was necessary to realign the camera, and frequently to readjust zoom and iris controls. For every adjustment of function and wipe settings, a further adjustment of azimuth and elevation was needed. The remote capability made it possible to perform these adjustments rapidly, from the console, and within view of the SEG monitor (7.2 (7.3)).

The remote capability did make it possible for camera 4 to serve four tasks (1, 2, 5, and 11). It was cumbersome, however, to move from task to task, an operation which usually required some searching in azimuth and elevation, followed by readjustment of focus, zoom and iris controls. This cannot be recommended as a practical means of covering different points in an actively changing task setting. An experiment at Task 5, in which camera 4 attempted, on call, to record students mounting the wheel, resulted in repeated failure to realign the camera in time to catch the action concerned (Table 8, note 6).

The remote control was useful, and in fact was required to make possible the pole climbing tests described at 8.0.

[Question 2.3.4] Remote Zoom:

The remote zoom was useful, and is an essential adjunct to other remote controls. It did not prove practical, in one experiment, to use that control to provide alternately detailed and perspective views of the wheel assembly subtask (7.3).

[Question 2.3.5] Remote Focus and Iris:

The remote focus and iris controls were useful as necessary adjuncts to other remote controls, since changes in azimuth, elevation and zoom frequently required readjustment of focus and iris (7.3). The iris control, particularly, was of value in adjusting to changes in light condition which were frequent under some circumstances (8.0).

[Question 2.3.6] Mirrors:

The use of mirrors was demonstrated successfully, and made it possible to monitor a fuel filter task which otherwise could not have been framed by a camera. Mirrors are of value in confined spaces, or where very narrow clearances exist between structures or structures and operators, through which a task must be viewed (7.8). A consideration is the fact that a mirror image is reversed.

10.4.4 Recording and Replay

[Question 2.4.1] Mechanically Controlled Recorders:

The mechanically controlled "Javelin" recorders are actuated by function keys set into the tape transport deck; they have the capability to record either at slow or fast tape speeds, and to produce speeded or slowed motion and stop-action. They operated reliably in all functions. Limitations were observed in their use at standard tape speeds: They were relatively difficult to actuate; careful, firm pressure was required to ensure that keys remained locked once depressed. Controlling the tape deck required enough effort and attention to detract from other console tasks; on occasion, action was lost due to the time required to start the recorder (Table 8, note 14).

Signal degradation (which is expected in video recording) was greater with this recorder than with the "Panasonic," and more degradation occurred in the record-replay process than in other subsystems of the video monitor. Signals which were in any way defective at input (as for example from poorly lighted subjects), recorded very poorly (Table 8, notes 8, 11 and 13).

When starting and stopping, the deck stresses the recording tape sufficiently to slightly deform the tape. As a result any point in a recording at which the tape had been stopped (as for instance to exercise the stop-frame function) tended to exhibit a synchronization flicker on further replaying.

Running the motor for any extended time when the transport is stopped causes local wear on the tape surface, since the magnetic material continues to bear against the rotating head. This made it convenient to use the "Javelin" in any application other than continuous recording or replay; in intermittent use it is desirable to turn off the

switch each time recording or play is interrupted. To start again, the motor must be switched on, and given time to gain synchronous speed, before the tape deck is actuated.

[Question 2.4.2] Remotely Controlled Recorders:

The remotely controlled "Panasonic" recorder was less flexible in function but much easier to use, and made a superior recording. Record-replay degradation was a limitation, but was less severe than in the case of the "Javelin". The convenience of push-button function control was of greater value than expected (8.0). Finally, since this tape deck has a provision for automatically lifting the tape off the recording head, tape wear during stand-by periods was not a problem.

[Question 2.4.3] Slow Tape-speed Recording:

In several applications, studying subtasks of the aircraft maintenance task and in instructor training, it was found that no significant loss of information resulted from recording and replaying action at the slow tape speed of 7 frames per second (Table 8, note 15) (Table 9, note 5) (9.0). This economy produced a slightly flickering and discontinuous motion, but evaluation criteria were fully discernable. In the pole climbing task, however, where judgement of body coordination was critical, full speed recording was required (8.0).

[Question 2.4.4] Stopped Action:

Stopped action was demonstrated to be an adequate mode in which to examine most maintenance tasks - or any task in which product criterion is applied in the complete absence of a process observation. However, due to the inconvenience of searching the tape to find criterion points, it was deemed more economical of time and effort to review maintenance tasks using speed motion (Table 7, note 9) (Table 8, note 17). As has

been noted, in stopped-frame mode the playback head continuously turns against the same magnetic tape face, causing significant wear on the surface.

[Question 2.4.5] Slowed Action:

Although there are known applications for slowed-action replay, none were found which were of advantage during the field test.

[Question 2.4.6] Speeded Action:

Speeded action was found very useful as a means of economizing time in reviewing recorded sequences. Speeded motion in maintenance tasks resulted in some blurring of hand and tool movements, and a presentation which at first seemed ludicrous, but was recognized as the optimum means of scoring most such tasks (Table 7, note 8) (Table 8, note 16) (Table 9, note 5).

[Question 2.4.7] Tape Addressing:

The automatic rewind/addressing capability of the "Panasonic" recorder was of advantage in that it made it possible automatically to return to the beginning of any predetermined recorded sequence. It did not greatly assist in the general problem of finding the address on tape of previously recorded material.

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SECTION 11.0 RECOMMENDATIONS

Based on findings the following recommendations are made:

11.1 GENERAL

The Video Observation System has utility in training and in testing. USAF should apply the system experimentally in additional schools and settings. It can be of value to:

- o Support training or testing operationally.
- o Explore any specifically proposed testing or training application, determine whether video techniques can be applied in the setting concerned, and experimentally determine what video equipment is optimal for a permanent installation.

11.2 OPERATIONAL SYSTEM - POWER LINEMEN COURSE

There is a current requirement for video support to the power line-men course (reference paragraph 8.4). A functional system should be provided for that course, and used immediately in student selection. Cost of a basic system configuration as suggested (8.4) is in the \$5,000 range. That cost will be recovered by a very few instances of students either (1) eliminated before they fail, (2) saved from improper pretest failure, or (3) saved from needless self elimination. The cost can be further justified by use in other training applications, and in behavioral research.

11.3 SYSTEM UPGRADING

Future procurement of a similar system, redesign, or modification of the present system is likely. It is suggested that in such a case the following options be considered:

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- o An alternative lowboy camera mounting be identified which is stable when mounting the remote control cameras, and which permits remote control movement in azimuth and free movement in elevation.
- o Alternatives to the present audio intercom system be studied, including headset systems and provision for the automatic identification of the outstation calling.
- o Switching be provided by which cameras 5, 6, 7 or 8 can be connected to a SEG or recorder, without going through the SEQ.

APPENDIX I

QUESTIONS INVESTIGATED

1.0 INSTRUCTION AND EVALUATION

1.1 What is the process/product content?

1.1.1 What product criterion points are critical to evaluation of any task?

1.1.2 Which are/are not fully monitorable by video?

1.1.3 What gains/losses in precision or effectiveness of product criterion measurement would result from limiting testing to video measurements?

1.1.4 What gains/losses in economy of effort would result from limiting testing to video measurements?

1.1.5 Are any significant process measures possible which video measurement would facilitate?

1.2 What are the student/evaluator feedback effects?

1.2.1 Does the present measurement practice provide adequate remediation?

1.2.2 Could video improve student/instructor feedback?

1.3 What times are involved?

1.3.1 What approximate mean instructor time is required (present methods) to perform an instructor verification of any correct subtask?

1.3.2 What approximate mean time is required (present methods) to provide remediation and achieve criterion performance, when subjects exhibit errors or incompetence on the first try?

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1.3.3 What approximate mean time is required to verify correct performance using the video monitor, including any effort required for student contact or direct visual inspection?

1.3.4 What estimated mean time would be required to provide remediation, using an ideal video monitor system?

1.4 Could recorded work samples be used to increase instructor reliability, or for other evaluative purpose?

2.0 VIDEOTECHNICAL CAPABILITIES AND OPERATOR LOADS

2.1 Video feasibility. Is it technically feasible to monitor or record critical (criterion) elements of specific tasks, using the experimental video system?

2.1.1 Access. Can cameras gain video access to the task?

2.1.2 Obstructions. Are limitations on visibility imposed by blocking by the subject, his hands, tools, or aircraft structure?

2.1.3 Camera requirements - product criteria. Can all product criterion features be framed by:

- o a single fixed camera?
- o 2 or more fixed cameras?
- o remotely controlled (tilt, azimuth, zoom) cameras?

2.1.4 Camera requirements - process. Can all process (activity) features of the task be framed by:

- o a single fixed camera?
- o 2 or more fixed cameras?
- o remotely controlled (tilt, azimuth, zoom) cameras?

2.1.6 Resolution/discrimination. Are limitations imposed by:

- o lack of field contrast?
- o smallness of critical detail?
- o degradation of image in switching, special effects or recording?

2.2 Supporting Audio. Is supporting audio useful or required?

2.2.1 Is audio monitor or record capability needed (cost-effective)?

- o What operator loads are imposed by use of the audio monitor/record capability?

2.2.2 Is intercom capability needed:

- o to call work stations?
- o to call the control console?
- o to pass criterion (test) information?
- o to control recording?
- o What operator loads are imposed by use of the intercom system?

2.3 Subsystem capabilities. What are the utilities and limits of specific subsystems?

2.3.1 SEQ. Can cameras 5-8 be set up, monitored and applied to measurement tasks using the sequential switch?

- o For what is the SEQ useful?
- o What limits does it impose?
- o What additional operator load is imposed by monitoring cameras and tasks through the sequential switch?
- o What switching speeds are effective for what applications?
- o How many tasks can an operator keep under surveillance through the SEQ?
- o What operator load is imposed by operating the manual switch?

2.3.3 Remote pan/tilt. Using the remote control pan/tilt capability of cameras 3 and 4, can the console operator capture video information not otherwise viewable?

- o Can he follow moving action in azimuth and elevation?
- o Can he pan from one subtask to another?
- o What uses apply?
- o What limitations has this capability?

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- o What operator load is imposed by remote control of azimuth and range?
- o What are the cost/benefits in following a moving target?
- o What are the cost/benefits in panning between two targets?

2.3.4 Remote zoom. Using the remote zoom and focus capability, can the console operator capture video information not otherwise viewable?

- o Can he change content of the video frame to include changing levels of detail?
- o What uses apply?
- o What limitations has this capability?
- o What are the operator loads and cost/benefits in changing the video frame content by use of remote zoom control?

2.3.5 Remote focus and iris. Can the console operator effectively adjust focus and iris by remote control?

- o Under what conditions is this useful?
- o What limitations has this capability?
- o What operator loads are imposed by changing remote focus and iris adjustment?

2.3.6 Mirrors. Can video access to difficult targets be achieved using mirrors?

- o For what applications are mirrors useful?
- o What limitations do they have?

2.4 Recording and Replay. Is it technically feasible to record and replay critical elements of specific measurement tasks, using the experimental video system?

2.4.1 Mechanically controlled recorders. Do the mechanically controlled Javelin recorders effectively record criterion product and/or process data (at standard tape speed)?

- o What are their capabilities?
- o What are their limitations?
- o What operator loads are imposed by the mechanically controlled recorders?

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2.4.2 Remote control recorders. Do the remotely controlled Panasonic recorders effectively record criterion product and/or process data?

- o What are their capabilities?
- o What are their limitations?
- o What operator loads are imposed by the remotely controlled recorders?

2.4.3 Slow tape-speed recording. Can video data be effectively recorded and replayed at 7 frames per second?

- o For what is this capability useful?
- o What limitations does it impose?
- o What operator loads are imposed by slow speeds?

2.4.4 Stop action. Can useful information be derived by using the stop-frame capability?

- o What operator loads are imposed by recording and observing stop-frame action?
- o Under what conditions is this useful?
- o What limitations does it impose?

2.4.5 Slowed action. Can useful information be derived using the slowed action capability?

- o Under what conditions is this useful?
- o What limits does it impose?
- o What operator loads are imposed by recording and observing slowed action?

2.4.6 Speeded action. Can time be saved by viewing task performance as speeded action?

- o Under what conditions is this useful?
- o What limits does it impose?
- o What operator loads are imposed by recording and observing speeded action?

2.4.7 Tape addressing. Is the automatic rewind/address capability of the Panasonic recorder useful?

- o What loads are imposed by searching tapes for the addresses of specific sequences to be reviewed?

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APPENDIX II

VIDEO SAMPLE LOGS

Following are copies of the original Video Sample Logs made during the field test of the Video System. They reflect contents of the performance sample tapes which have been furnished to the Air Force.

VIDEO SAMPLE LOG

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TAPE #		VTR #		DATE	
1		2		17 May 73	
INDEX	SUBJECT	TASK	CAMERA	SEG	TECH COMMENTS
000- 211	GARRETT	9	3	-	Camera 3 sitting against wing tank. 18" above floor, 70" above & above, 5' from wing hinge. Light at 7:30, head with work, just under wing. Barn door adjusted to shield glass off landing gear. Last light at 8:00, floor level, under wing tank.
211- 348	ELMER	9	2	-	Camera 2 sitting by rear of wing tank. Subject obstructs view. Note Subject adjusts strut length while off camera.
350- 480	BRIDWELL	9	3		Camera 3, same as at 000 but without light at 2. Subject complains of heat. Slow record.
480- 664	LATHAM	13	8	-	Camera 8 shoots thru mirror using wide angle lens. - light from overhead rear, standing on compartment floor.
					END

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VIDEO SAMPLE LOG

VIDEO SAMPLE LOG					TAPE #	VTR #	DATE
					2	1	18 May 73
INDEX	SUBJECT	TASK	CAMERA	SEG	TECH COMMENTS		
000 -	SCHEREN	5	1+4	1	Camera placement: See diagram. Light at 5 o'clock, 8 ft from wheel side. Shot side natural light.		
218					Note ⑤ spends much time looking at T.O., and if goes often looks in completely off camera.		
226 -	HIRHER	5	1+4	1	Slow speed. Turret camera 4 on SEG of upper right		
252 -	CABREROS	5	1+4	1	" "		
284	RODGERS	5	1+4	1	" " Zoom camera 4 to frame wheel nut only.		
319	CARTER	5	1+4	1	" "		
371	GORDON	5	1+4	1	" " Change SEG to noticeably right screen		
071	DURGIN	5	1+4	1	" "		
415					Note: This is only ⑤ who shows evidence of reacting to observation.		
END					END		

VIDEO SAMPLE LOG

TAPE #

VTB 3

DATE

3

17 May 93

INDEX	SUBJECT	TASK	CAMERA	SEC	TECH COMMENTS
000 - 232	WEIS	1	6+4	2	Camera 6 at 9 o'clock, 8 feet. light from under wing at 1100. Camera 4 for grass ⑤ move- ments from 6:00 and 10 feet, looks down over tail surface to work area. light is secured from camera 4 by wing tank tail surface. Tant 4 on SEG corner in seat.
233- 415	WILKINS	1	6+4	2	
415- 510	WESTDERRY	1	6+4	2	
510 - 534	EDGERLEE	1	6+4	2	Afternoon lighting. All light from under R Tail section at 7:00 x 10 ft. Slow Tape Speed
534- 563	ALLEN	1	6+4	2	Slow speed
563- 578	SEALY	1	6+4	2	"
578- END	ALLISON	1	6+4	2	"
					END

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VIDEO SAMPLE LOG				TAPE #2	VTR #	DATE
INDEX	SUBJECT	TASK	CAMERA/SEG			
				B 4	/	22 May 73

INDEX	SUBJECT	TASK	CAMERA	SEG	TECH COMMENTS
0-189	Video system configuration	-	3	-	Overall views of jet mechanic test area and camera and console locations
198-249	Console operation				Demonstration of typical operator functioning normal and slow speed recordings of strut linkage, Bungee removal and replacement, and wheel removal and replacement
250-430	Sample Test Tests				END

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VIDEO SAMPLE LOG			TAPE #	VTR #	DATE
			5	3	22 May 93

VTR #

3

71

TIA

INDEX	SUBJECT	TASK	CAMERA	SECS	TECH COMMENTS
000 -	—	5			Takes 36-75' last.
227	—	5			Increment performance of wheel brace task.
227-630					END

209

VIDEO SAMPLE LOG			
TAPE #	VTR #	DATE	
6	1	23 Aug 73	

VTR #

DATE _____

5

23 May 73

INDEX	SUBJECT	TASK	CANSEA	SEG	TECH COMMENTS
0-74	507 Aircraft Test Test K3		125-7		Sample of test performances recorded at slow speed for review and evaluation via speeded playback.

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